A Foraminiferal Biostratigraphy of the Lower Senonian of Southern England.

by

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being a thesis submitted for the degree of

Doctor of Philosphy

to

The Council for National Academic Awards.

Research conducted at Plymouth Polytechnic

May 1978.

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ACKNOWLEDGEMENTS

This research was carried out under the authority of the Council for National Academic Awards whilst I was employed as Research Assistant by Plymouth Polytechnic. During the course of the study numerous people have been called upon for their advice and assistance. Whilst it is impossible to acknowledge the part played by every individual I am indebted to all those who have been involved.

I am extremely grateful for the persistant interest, help and attention given by my supervisors Dr. Malcolm Hart and Mr. Dave Carter, who both played a major part in initiating this work. I would also like to acknowledge the discussions held with Pete Manley and Phil Weaver, both of whom also helped with the field work involved in the project.

The samples derived from the Thames Barrier Site Investigation were kindly supplied by Foundation Engineering Ltd. Three core samples from Essex were also supplied by the Institute of Geological Sciences, and I would like to thank Chris Wood and Peter Bigg for bringing this material to my attention, and for all the other help they have given.

Several research workers have kindly supplied me with publications, information and comparative samples, particularly Hartmut Ernst, Dr. Jake Hancock, Dr. W.J. Kennedy, Dr. Wilhelm Koch, Dr. Bernhard Porthault and Dr. Francis Robaszynski. All of this data has been useful in co-ordinating a more general view of Late Cretaceous events in Europe.

The technical side of producing this work has involved numerous people all of whom have been very willing to assist. The scanning electron microscope work was carried out at the Royal Naval Engineering College, Manadon, Plymouth with the permission of Commander Brian Gibson (Head of Materials Technology). Derek Sargeant and R.E.A. (2) Stuart Grimes provided continuous direction and assistance and Brian Lakey also gave valuable advice and instruction. The production of the photographs and plates was carried out by Betty Fox and Steve Johnson. Technical assistance was also given by Pete Bloomfield and his staff, both in processing samples, and thin section work.

I am also indebted to Dave Howard, who translated large amounts of Russian text and to Dr. John Harvey who provided several German translations.

As I am now a member of the staff of Paleoservices Ltd. (Watford) production of the final draft has been carried out there. I wish to thank the directors Dr. Vittorio Roveda and Dr. Deryck Bayliss for their encouragement, and for making their facilities available to me. I am particularly grateful to Lesley Adams who has patiently typed the final copy of this study.

Finally, this work could not have been carried out without the assistance and encouragement of my parents, and it could only have been completed with the unflagging patience, support and understanding of my wife Jan.

DECLARATION

During the course of this research a short paper was presented by the author to the Ussher Society, entitled "A preliminary microfaunal investigation of the Lower Senonian at Beer, south-east Devon". A copy of this publication is enclosed with this thesis.

ABSTRACT

The necessity for a micropalaeontological examination of the lower Senonian chalk of southern England was established during the site investigation of the Thames Barrier, which is founded on chalk of the Micraster zones.

There has been a large amount of detailed stratigraphic and micropalaeontological research carried out on the Late Cretaceous deposits of Europe, and this provides a historical framework onto which the present research is placed.

Samples from three of the Thames Barrier boreholes were studied initially to provide an indication of the microfauna and it's stratigraphic setting. This was followed by the collection and examination of a further seven sections from the Micraster zones of Rowe (1900-1908). The localities selected give a geographical coverage of most of southern England. Single samples from three other localities have also been included.

The microfauna observed shows a trend of increasing diversity from the base of the Coniacian through into the Santonian. One hundred and twenty seven taxa have been described, the majority for the first time from the English succession, and this includes twenty taxa which have no previous recorded descriptions.

The trend of increasing faunal diversity noted, makes the establishment of a zonation possible, based on the appearances and extinctions of twenty-five benthonic foraminiferal taxa. This zonation, when applied to all the sections studied, allows a correlation across the whole of southern England.

Lower Senonian foraminiferal faunas reported from the rest of Europe have been compared with those recorded in this country. Not only does this present a large amount of stratigraphic data, but it also gives an indication of the palaeogeographic setting of the region during the Late Cretaceous.

INTRODUCTION

Micropalaeontology has been a valuable tool of the applied geologist over approximately sixty years, and this has been well illustrated in those areas of the world where financial support for research has been forth-coming from the industrial sector. During the last two decades the expansion of applied geology in and around the United Kingdom, as part of the exploration for energy resources, has highlighted our limited knowledge of Upper Cretaceous stratigraphy.

Since the early part of the 1960s therefore, there has been a rapid growth of interest in all aspects of the English Chalk, including a large amount of micropalaeontological investigation. Williams - Mitchell (1948) was the first person to indicate the direction further research might take, when he outlined a broad foraminiferal zonation for the Upper Cretaceous of England. The detailed study of the total microfaunal assemblage at specific stratigraphic levels did not commence however until 1962, when Jefferies made a complete analysis of the palaeontology and stratigraphy of the Actinocamax plenus Subzone. This included a study of the foraminiferal content.

By 1964/65 research had been stimulated further by the micro-palaeontological studies of the Channel Tunnel Site Investigation. This resulted in the formulation of a foraminiferal zonation of the Albian and Cenomanian Stages by D. J. Carter, the micropalaeontologist involved in the investigation. This work was followed up by that of Hart, who completed the analysis of the microfauna of these stages in south western England in 1970.

In the same year, Owen completed his research on the Foraminiferida of the Turonian, extending the detailed foraminiferal zonation a stage further.

The lower Senonian, however, remained unexamined, a situation which was illustrated when D. J. Carter and M. B. Hart carried out a microfaunal correlation of the boreholes drilled during the Thames Barrier Site Investigation at Woolwich (see Hart and Carter 1975, Carter and Hart, in press A).

This investigation indicated that faunal changes could be identified in this part of the Chalk succession, and that a more detailed study might yield a viable micropalaeontological zonation. This proved to be the foundation of the present work, which is an attempt to erect a zonal scheme for the lower Senonian of southern England.

During the course of this study, it was found that the benthonic foraminiferal population provided the most dependable stratigraphic indicators. Thus a zonal analysis evolved using this part of the fauna. The planktonic foraminifera were also examined, these providing much additional information, both stratigraphic and taxonomic. Elements of this group were employed in the correlation of the English sequence with the world planktonic foraminiferal zonation (van Hinte 1976).

Comparative studies were sought in other parts of Europe, as published information on the English fauna was restricted to that of Barnard and Banner (1953), Barnard (1958, 1962, 1963, 1973) and Barr (1962). The work of Brotzen (1934 - 1948) was found to be invaluable, as his investigations in southern Scandinavia yielded many of the original descriptions of the fauna encountered in this country. Other major contributions, such as those of Franke (1925, 1928) working in northern Germany, Marie (1941) examening the Upper Chalk of the Paris Basin, and Vasilenko (1961) investigating the microfauna of the Mangyschlak Peninsula in southern Russia, all proved to be valuable in building up an overall picture of the fauna and its geographical associations.

More recently, work by Porthault (1970, 1974), Koch (1973) and Norling (1973) have continued to provide useful sections for comparison with the British succession.

In order to analyse this stratigraphic level in southern England, ten major sections have been studied, and in addition, numerous individual samples have been used for comparison. This has resulted in the examination of over 540 samples, from which all the data given in this work are derived.

One hundred and thirty different species and varieties of Foraminifera have been described, although only twenty-five of these have been used in defining the zonal scheme. Twenty species were encountered for the first time and a large number of the remainder are described fully for the first time from this country.

The general aspect of the fauna is one of a gradually expanding assemblage, with a uniform increase in diversity. Several species are notably long-ranging and these are present from the Cenomanian through the Senonian, under one trivial name or another. However, from the base of the Coniacian the faunal diversity increases with a development of the Cassidulinacea and Buliminacea. It is members of these superfamilies, along with the Orbitoidacea which provide the basic framework of the zonal scheme.

This zonation has been applied to each of the sections studied and a successful correlation has been established between them. It is believed that it may also be applied to other sections in southern England with the same degree of success. Thus, the lower Senonian has been examined and a zonal scheme established for the southern part of the country.

Material from further north, around Yorkshire and Lincolnshire has not been studied, apart from a few samples, although a correlation is thought possible.

The suggested zonation has been extended stratigraphically as high as the Lower Santonian, and the fauna by this level has become quite distinct from that seen at the base of the section. It is believed that with further work, the scheme could be continued to higher levels along the lines indicated by Williams - Mitchell in 1948.

The Upper Cretaceous succession is important economically, both in the fields of oil exploration and civil engineering. Thus a full understanding of the microfauna is an essential tool in the long term investigation of the chalk. We still do not fully comprehend numerous aspects of this unique period in stratigraphic history, and it is hoped that this work might provide a little of the information required in the solving of a few of the problems.

CHAPTER 1.

HISTORY OF PREVIOUS RESEARCH.

During the last one hundred and fifty years there has been a continual flow of research directed towards the overall biostratigraphy of the Upper Cretaceous. This flow has varied in strength at times, mainly dependant on the personalities involved, and their individual motivations. Their work has continued to increase our understanding of the complexities of Chalk stratigraphy, depositional environments and subsequent diagenesis, but one thing is clear, our understanding is far from complete.

The present chapter has been divided into three sections concerned with stratigraphy, lithology and micropalaeontology of the Chalk, each discussing the relevant works which have been used in the present study. Obviously overlaps occur between all three sections, and these will be referred to in each section as necessary.

Attention is particularly drawn to the sole previous attempt to define a micropalaeontological zonation for the Upper Cretaceous of southern England. This was the work of Williams-Mitchell (1948), which laid down the foundation for a firm foraminiferal zonation, a foundation which has only more recently been built upon.

1:1 Stratigraphy

The sub-division of the English Chalk has long been founded on lithological units, commencing with William Smith's three-fold division of the Upper Cretaceous of southern England into the Gault, Greensand and Chalk. Working concurrently with Smith, and publishing early notes on the English succession were Mantell (1819, 1833), Daniell (1818) Fitton (1824, 1836) and Woodward (1833).

These men along with several others provided the early stimulus to the work carried out by the early members of the Geological Survey. Notable among these were Bristow (1862) and Whitaker, who produced several important papers concerning the chalk of the southern England coast (1865, 1871 a–c), which sub-divided it into seven lithological units. Evans (1870) is also notable, as his was the first attempt to use fossil zones in order to correlate separate chalk sections in this country.

Whilst this work was being continued as part of the geological mapping of southern England by the Survey, geologists in France were unknowingly establishing the basis for future international Upper Cretaceous stratigraphy. In northern Aquitaine the succession present in the areas of Dordogne and Charente were studied for the first time by d'Archiac (1836), who based his early stratigraphy, like his English contemporaries, mainly on lithological features. Work in this area was continued by Coquand (1856), who established a nomenclatural framework based on the divisions of d'Archiac.

Coquand totally revised his own work in 1858 in his definitive work on the department of Charente, in which classic biostratigraphical methods were used. He stressed "the utilisation of palaeontological criteria to replace the mineralogical and lithological criteria used previously" along with "the adoption of one special and univocal name for each of the stages defined". It is also interesting to note that Coquand recognised the synchronism of the latest Cretaceous beds ("Chalk beds") of Aquitaine and the chalks of Meudon and Maastricht.

Thus the "Stages" referred to as the Coniacian, Santonian, and Campanian were established, although debate continued as the validity of these names (Arnaud 1878), finally reducing them to substages (Gignoux 1926) by equating them with the Senonian stage erected by Alcide d'Orbigny in 1842.

The early work of d'Orbigny in the use of palaeontological zones cannot be underestimated, especially in conjunction with his study of the microfauna of the Paris Basin (1840), which established many of the species names found in the present study. These investigations were complemented, during the period 1858 to 1875, by a whole series of papers written by Hébert (1863, 1866, 1872, 1875) examining the Upper Cretaceous deposits of the Paris Basin. His division of the Senonian into distinct palaeontological zones is still the same as that used at present. This work was expanded across the English Channel by Hébert (1874), at first on a limited basis, and then more ambitiously by Barrois (1875, 1876) who attempted, quite successfully, to establish a biostratigraphy for the Upper Cretaceous of southern England.

Minor disagreements occurred following this work, when the palaeontological criteria were adopted by the members of the Geological Survey. Fortunately the major work on the Chalk was continued by Jukes - Browne and W. Hill who, using the zones outlined by Hébert, finalised a vast amount of research with the production of "The Cretaceous Rocks of Britain", which ran to three volumes between 1900 and 1904. The third volume, describing the Upper Chalk summarises most of the knowledge available at that time with regard to the British succession and it represents a milestone in English stratigraphy.

Working at the same time as Jukes-Browne and Hill, were two stratigraphers of a more amateur status, although their work cannot be considered as such. Arthur Rowe published his first important contribution, discussing the echinoid genus Micraster, in 1899. This was rapidly followed by a succession of five major regional works (1900-1908) jointly titled "The zones of the White Chalk of the English Coast".

. These represent a tremendous amount of detailed field work, and it is clear that although Rowe states that lithological markers are not valid in the division of palaeontological zones, he uses them to great effect wherever possible. Thus approximate junctions for fossil zones can be recognised in the field on the basis of easily identifiable lithological horizons. It is this ease of recognition which prompted the present author to use certain of Rowe's marker horizons, in a number of localities, as an aid to detailed sampling.

Brydone also devoted most of his free time to field work, visiting every chalk outcrop noted on the 6" series maps of Hampshire, and compiling his notes to produce "The Stratigraphy of the Chalk of Hants" in 1912. This was rapidly followed by two more papers (1913, 1914) devoted to the Offaster pillula Zone in southern England.

With the completion of the works listed by these three men, Jukes-Browne, Rowe and Brydone, along with contributions made by a few others such as Strahan (1891, 1896), Cretaceous stratigraphy in this country was considered to be fairly well established and research continued on a much reduced scale. Gaster completed an extensive study of the Chalk of Sussex between 1924 and 1951, and Osborne-White continued the work of the Geological Survey. The memoirs he produced on the Isle of Wight (1921) and the country around Dover (1928) are considered to be largely a revision of Rowe's work with few new contributions.

There followed a long period of almost forty years, during which little research was directed towards the Cretaceous stratigraphy of this country, a gap which was to finally close during the early 1960s with the advent of renewed interest in the Chalk.

. It was acknowledged that much of the work completed at the beginning of this century was in need of revision, and the first step was that of Jefferies in his work on the Stratigraphy of the *Actinocamax plenus* Subzone (1962, 1963).

Kennedy (1969, 1970) did much to analyse the stratigraphy of the Late Albian and Cenomanian of southern England, and Peake and Hancock examined the Chalk of Norfolk (1961, 1970). Hancock has continued to produce interesting accounts of the Upper Chalk succession of this country, although both his work and that of Kennedy, has become directed towards the petrography and lithogenesis of the sediment rather than the stratigraphy.

Detailed stratigraphical work has continued in northern Germany (Ernst 1970, Ernst et al 1974) and to a lesser extent in southern Scandinavia (Christiensen 1975, Bergström et al, 1973) and it would appear that British stratigraphy now seems inclined towards macrofaunal zonations established in these areas, rather than the original French localities. This is understandable when the poor quality of some of the French sections is considered. However, in 1972 Mme. Séronie - Vivien fully redescribed the stratotypes and these Stages are still accepted as the International standard correlation. Any European zonation must, for the present, equate with them.

This guideline has been followed by the Geological Society of London working party on the Cretaceous (Casey et al, in press), which after much discussion finally adopted the zonation shown in Fig. 1.1. Further discussion regarding this work, is made in the chapter discussing the stratigraphic conclusions of the present study.

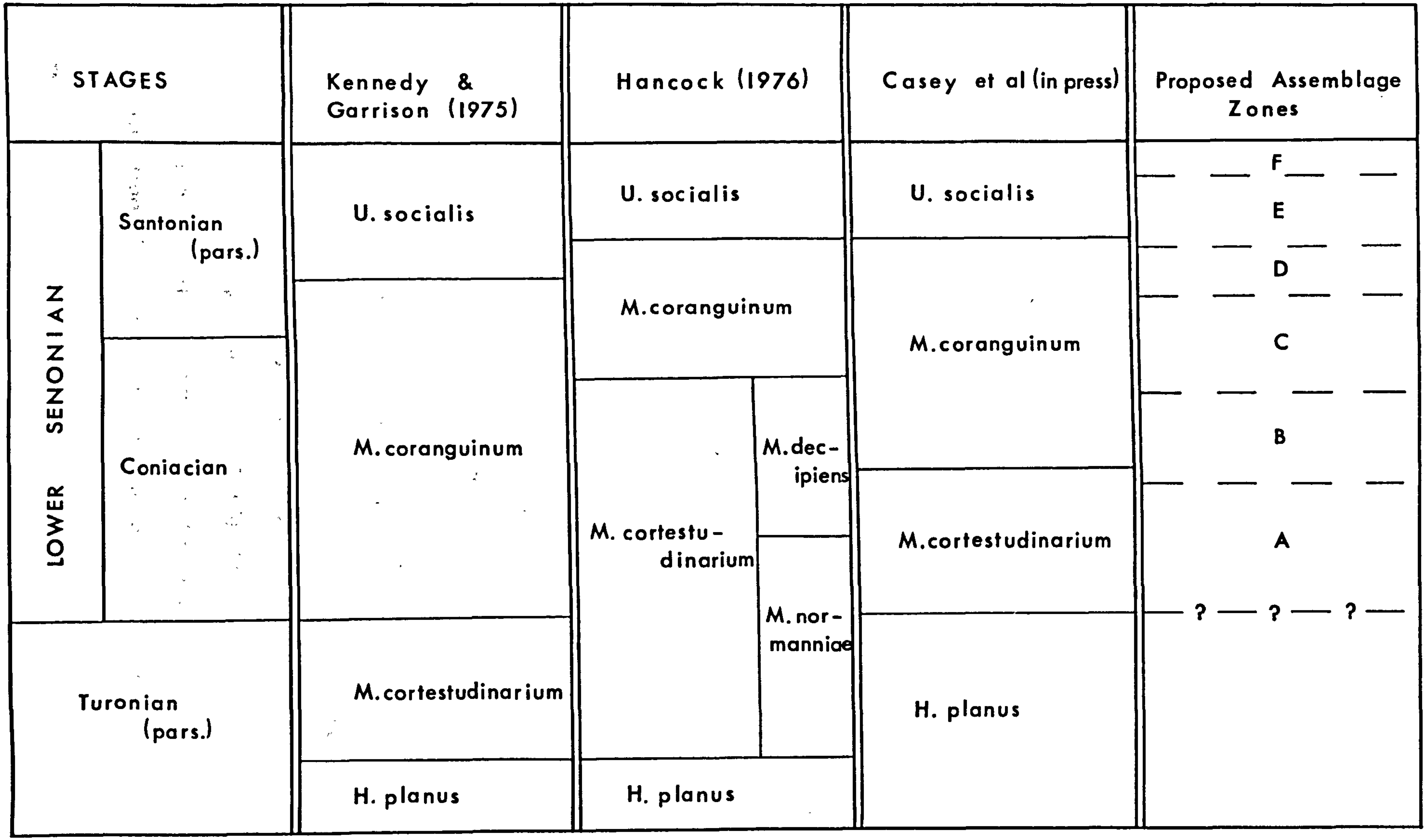

Fig. I:1 Comparison of recent zonations for the English lower Senonian. (Zonal thicknesses not to scale.)

1: 2 Lithology and Petrography.

Initial interest in Chalk petrography in this country was shown by Sorby (1861) in his discussion of "so-called 'crystalloids' ", which are now recognised as Coccoliths. Other than this, little work was published in the nineteenth century apart from Janet's (1891) note on the conditions of chalk deposition, this in turn was followed by similar work done by Grossouvre (1914).

The British also entered the debate concerning the depositional history of chalk, as Jukes-Browne and Hill (1904) devoted considerable discussion to features such as water depth and organic composition. In 1889 they also presented a paper concerning the presence of colloidal silica in the Lower Chalk. As with stratigraphical research little work was done following the 1904 publication, although Tarr (1925) seems to suggest that most of the calcium carbonate present in chalk is in-organic, thus disproving the older ideas of chalk being a foraminiferal ooze, even though his own ideas have been corrected since.

The present phase of interest in the Chalk commenced with the work of Black (1953, 1965) and Black and Barnes (1959), investigations into the true nature of the Chalk as a mass of Coccolith debris. The majority of the works which followed were devoted to the mineralogy and diagenesis of the sediment and these included Bromley (1965, 1967, 1968) and Kennedy and Garrison (1975 a,b) with discussions about chalk hard-grounds, Jeans (1967) and Weir and Catt (1965) on the mineralogy of chalk, and Wolfe (1968), Hancock and Kennedy (1967), Kennedy and Juignet (1974) and Scholle (1974) and the ultrastructure and lithification of various Upper Cretaceous deposits.

These, in conjunction with work done on the continent by Neugebauer (1973, 1974) and Håkansson, Bromley and Perch-Nielsen (1974), and in connection with North Sea exploration (Hancock and Scholle 1975), have led to a vastly improved understanding of the origin of chalk and all its related phenomena, although many of the ideas voiced recently are still in need of much attention.

1:3 Micropalaeontology.

At the beginning of the nineteenth century mention of Cretaceous foraminifera was made by Lamark (1804, 1806) and Nilsson (1827), but these comments are of minor importance when compared with those of two men, Alcide d'Orbigny and Alfred Reuss.

The former catalogued many of the important stratigraphic markers in his work on the foraminifera of the Paris Basin (1840), and his notes on Cuban material (1839) are also useful. Reuss, working in Germany and Central Europe, commenced his work on the Cretaceous with a major two part account of the Chalk fauna of Bohemia (1845, 1846), in which well over a hundred foraminiferal species were noted, the majority for the first time. Even though the diagrams in these two volumes are often poor for original figures, the sheer quantity of material studied gives them a position of prime importance in any discussion of Cretaceous foraminifera. He produced numerous other works of note (1851, 1854, 1855, 1860, 1862, 1863, 1866, 1874) which accounted for many of the type descriptions of foraminiferal species found in the Upper Cretaceous of North Western Europe. Elsewhere on the continent, sporadic papers of importance were published including those of Ehrenberg (1838, 1854), Marsson (1878), Beissel (1891) and Egger (1899).

Up to the turn of the century little microfaunal research had been carried out in this country, what there was had been done in the main by Jones (1882) and Parker and Jones (1872). The latter was the more important of the two, as the former is merely a catalogue of Chalk foraminifera with no descriptions or discussion. Another important worker was Chapman, whose main interest was a description of Albian and Cenomian assemblages although he did describe the Upper Chalk faunas of Taplow (1892) and Swanscombe (1894), which bear some relevance to the present study.

Wright (1886), describing the microfauna of the Northern Ireland succession, lists many useful species from the Senonian despite the inconsistency of lithology in the region. Apart from these four men only Jukes - Browne and Hill (1904) note the presence of foraminifera in the English Chalk, and even then, no use was made of them stratigraphically.

Rowe, although his principal work was devoted to the macrofauna and stratigraphy of the Chalk, did in the course of his study, gather together a vast collection of Foraminifera. This is now housed in the British Museum (Natural History) and the preservation and condition of much of it is remarkable. Unfortunately many of the slides remain unnamed, and the location and stratigraphic position for some specmens are difficult to determine.

Most of the European foraminiferal work for the Upper Cretaceous has been dominated by a number of major papers, which, in discussing the whole fauna, have taken on the proportions of monographs. These include the work of Franke (1925, 1928), Brotzen (1936) Marie (1941) and Vasilenko (1954, 1961).

Brotzen is possibly the most important author of this group, for when his 1936 work is combined with his publications of 1934, 1942 and 1945 his contribution to the present field of study is extremely significant.

In the U.S.A. the work of J.A. Cushman and his associates of the Cushman Laboratory for foraminiferal research, stimulated by the increasing demands of the oil exploration industry, documented much of the fauna present on the western side of the Atlantic. Their aim between 1920 and 1950 appears to have been to produce a taxonomy which was stratigraphically viable, which is an essential to any detailed foraminiferal investigation.

In 1948 investigations into the possibility of British oil fields, led to the production of a work entitled "The Zonal Value of Foraminifera in the Chalk of England" by Williams - Mitchell. Using borehole samples he tended to ignore palaeontological information in the interest of maintaining stratigraphic clarity. Choosing well-documented species, he compared borehole assemblages with those found in samples taken from established surface exposures, of known stratigraphic level. This was a preliminary study which called for a more detailed investigation, unfortunately this was not immediately forthcoming.

The results which Williams-Mitchell summarised in the form of a zonal table, have been found to hold true on numerous occasions, and the ranges he illustrated closely correlate with those found elsewhere in southern England. Any future work on foraminiferal zonation in this country, must take careful note of this early example of zonal analysis. The figures and species descriptions may be poor, but the zonation is good and easily applied.

Work continued in this country with that of Barnard and Banner (1953), on the arenaceous Foraminifera, which has proved to be useful taxonomically, as is the later work of Barnard (1958, 1962, 1963, 1972). This was complemented in a stratigraphic discussion of the planktonic Foraminifera by Barr (1962), who also went on to describe the fauna of an isolated pocket of Senonian chalk in southern Ireland (1966).

Both papers have proved useful for comparison with the details of the present study.

Concurrently with this, work in Germany by Hiltermann (1952), Hiltermann and Koch (1956, 1962) and Koch (1973), has produced a benthonic foraminiferal zonation, which can be usefully applied in this country. Hofkers work from the same area (1956, 1957) is important although often confusing, as his diagrams are poor and his taxonomy is often difficult to follow. Other European research workers have also provided more recent publications which have been valuable in the present study, these include Goel (1965), Trümper (1968) and Porthault (1970, 1974), the first two writing solely about benthonic forms.

The completion of the Treatise on Invertebrate Paleontology. Part C. - Protista by Loeblich and Tappan (1964) has formed the base of most of the foraminiferal investigations carried out since. Amendments to this work have been suggested, particularly with regard to the taxonomy of the Globigerinacea, (Pessagno 1967), but this is inevitable in any field of research.

Detailed studies of the planktonic foraminifera are numerous due to their stratigraphic value on a global scale. Those of Bolli (1951, 1957), Banner and Blow (1959), and Pessagno (1967) are selected examples from a much longer list, which is discussed within the Systematic Micropalaeontology. Bandy (1967) summarised the stratigraphic value of many of the planktonic species from the Cretaceous, as well as illustrating possible evolutionary lineages through this period. A further useful summary is that of van Hinte (1969), one of the many papers to arise out of the International Planktonic Conferences, the Geneva volume being of notable interest to Cretaceous foraminiferal research.

A passing note is also made to the work of Clarke and Verdier on the microplankton of the Chalk of the Isle of Wight (1967), as the stratigraphic discussion and description of the sections studied are relevant to the present study.

More recently a review of the present state of Cretaceous microfaunal research in southern England, has been produced by Hart and Carter (1975). This summarises the state of knowledge well and they note that work on the Upper Chalk is still much in progress.

1: 4 <u>Summary</u>.

An enormous amount of literature has been produced on Upper Cretaceous stratigraphy and more directly, on the Foraminifera used to correlate successions both on a regional and interregional basis. The overall approach of detailed chronostratigraphy is only just having a marked affect on the Cretaceous, in the light of deep sea drilling carried out in the ocean basins. This approach is expertly summarised by van Hinte (1976), in a work which should provide the foundation for most of the investigations still to be carried out.

CHAPTER 2.

SAMPLE COLLECTION AND ANALYSIS.

2: 1 Introduction.

Several accounts have been written as foraminiferal studies from the Chalk of this country, which have included comments on the collection and preparation of samples. Williams - Mitchell (1948), Barr (1962), Owen (1970) and Hart (1970, 1973) all give some indication of the techniques employed during their work, and it is clear that although the end results may be similar, the means used to obtain those results depend largely on the particular work concerned and the individual worker.

The Chalk shows considerable lithological variation, both vertically and geographically. Because of this, processing methods may vary correspondingly, in relation to the stratigraphic horizon under examination. In the present study the variations encountered are mainly a result of the diagenetic history of the sediment rather than its primary mineralogy, and the techniques used tend to be a reflection of the hardness caused by this history.

2: 2 Sample collection.

In defining the limits of the sections to be collected, the Micraster zones were used as a rough guideline. The most comprehensive published description of these zones is still that given by Rowe (1900-1908), and more recent publications (Barr 1962, Clarke and Verdier 1967) tend to follow the boundaries which he suggested. His use of plainly visible, lithological marker horizons to indicate the upper and lower limits of the macrofaunal zones, acts as a framework upon which detailed sampling may be based.

These lithological boundaries are accepted simply as a guide and imperfections in their stratigraphic positioning are acknowledged. In fact an error in the upper limit of one of the sections studied, and therefore in that of the Micraster coranguinum Zone, is postulated in the light of results from the present study.

The zonal limits indicated by Rowe have been followed on several major sections, although care has been taken to sample both above and below the Micraster zones, as he defined them. Thereby reducing the margin of error in correlation between sections.

The majority of the successions examined were massive, open cliff sections, which demanded continuous sampling at regular intervals. A spacing of 1 metre was therefore selected as the most practicable under the circumstances, although this gap was reduced to 0.5 metres at critical levels and even down to 0.25 metres in one or two specific instances. Anything less than that was considered to be within the range of bioturbation (Berger and Heath, 1968), and the results obtained therefore suspect. In the sections taken in Norfolk and at Quidhampton the interval was increased to 2 metres, and these localities have been used mainly for comparison with the more complete coastal outcrops.

This use of a regular sampling interval equated well with that found in the borehole sections from the Thames Barrier Site Investigation. This consisted of a series of drill holes across and on, both banks of the River Thames at Woolwich (Carter & Hart, in press A). Material from several of the cores were examined in the initial stages of this project, as samples from the cores were already processed. It therefore provided much of the early data, which were then used in the selection of further sites for investigation.

The samples taken for this study were in the form of fresh blocks, weighing between 0.5 to 1 kilogram, and selected from as narrow a stratigraphic thickness as could be physically achieved, normally 8 to 10 centimetres. Loose and down washed debris was cleaned off prior to packing, and each of the samples were carefully labelled, both in the sample bag and in a field note book to provide a cross-reference.

Material was also collected from marl seams, incipient hardgrounds and in the form of soft meal from the cores of cavernous flints. Because of their peculiar preservation, these spot samples often yielded useful information for comparison with the continuous chalk section. The significance of some of these samples is discussed in a further section, primarily concerned with the affects of preservation on the results obtained.

Throughout the field work notes were made on the macrofaunal elements found in the course of close lithological examination. Examples of the fossils found were collected and details of the horizons at which they were located were taken for reference.

2: 3 Processing Methods

Much of the chalk collected in the course of this work has proved to be so hard that chemical methods of disaggregation have been unsuccessful.

Initially, the procedure outlined by Owen (1970) was adopted, using hydrogen peroxide solution, in which small lumps of the sample were boiled for a considerable length of time. This proved to have little effect until it was adapted in the later stages of the research.

Small lumps, approximately one or two centimetres cubed, were first thoroughly dried in a warm oven over a period of days. Whilst they were still warm, a concentrated 40% solution of hydrogen peroxide was poured over them, and if necessary they were boiled for a short period. This had the effect of breaking down the outer surfaces of the pieces of chalk, so that when this fine material was removed, the sample could be redried and the whole process repeated, until enough residue was obtained to provide a reasonable fauna.

For the most part however, purely physical techiques were used, similar to those described by Williams - Mitchell (1948). The basic method was as follows:-

a) the fresh sample was broken into small lumps, as in the previous method. It was then thoroughly soaked in water, often for a period of up to twenty-four hours.

b) The chalk was carefully crushed with a cast iron mortar and pestle, taking great care to ensure that the residue was not broken down excessively.

c) This residue was then washed through a 75 micron sieve to remove the fine material. Following this it was agitated in an electric mixer for a very short time, with the addition of a high grade detergent, such as Decon 90, to remove fine debris adhering to specimens.

d) The sample was again washed through the 75 micron sieve, emptied into a basin and finally dried in a warm oven.

At each stage of this procedure extreme care was taken to ensure that all the equipment was cleaned, thus cutting down the risk of contamination between samples. It is also worth noting that the present samples were the only material being processed in the laboratory, at any one time. This in an attempt to minimise any contamination.

As a result of the hardness of some of the chalk studied, thin sections were cut to give some indication of the fauna. This method has its value in the identification of planktonic foraminifera, although the majority of the assemblage can only be identified at a generic or even family level.

2: 4 Sample examination and Assemblage counts.

The dry residue was first sieved through a series of standard size meshes, measuring 1.7 milimetres, 500, 250 and 180 microns, the finest material being retained in a basal sieve pan, each size fraction was then examined, along the lines indicated by Hart (1970, 1973).

For the residue greater than 500 microns in size, a complete faunal list was compiled. This procedure was repeated for the material present in the 180 micron sieve and the base. These latter two units form what has been referred to as the fine fraction. The fauna present in the 250 micron sieve was accounted for in one of two ways.

a) A total count of approximately 400 specimens was made, mounting each of them onto a gummed microfaunal slide, allowing for later reference and detailed examination. A faunal list was compiled indicating the total number of each species present.

b) A faunal count was carried out using a data sheet prepared for this study. This count was normally continued until over 750 specimens had been noted and identified. Specimens of particular interest were extracted from the sample was stored on single or multiple celled microfaunal slides.

One of these two methods has been used for each of the samples studied, including individual spot samples taken for comparison. After each count the sample underwent a further lengthy examination to ensure that no other species, unaccounted for in the faunal list, were present.

It is this 250 micron size faunal count which has been used in the numerical and graphical analysis of the samples. The reason for the isolation of this group has been noted on several occasions, (Hart 1973, Bailey 1975, Hart and Carter 1975) and stems from the belief that the adult stages of the majority of the foraminiferal species noted in this study occur within this size fraction.

Serious attention has been given to those species which only occur in the finer fractions of the residue. Several of these are extremely significant stratigraphically, which has led to a careful examination of this material, even though a numerical analysis was not carried out.

Throughout this study recognition and limited identification of the ostracoda and elements of the macrofauna was made. Changes in the residual mineralogy were also noted as these often yielded information of a general value, and attimeshad a palaeoecological significance.

2: 5 Analysis and Presentation of data.

Having compiled species counts in absolute numbers, the results were then recalculated to give the relative proportions of different species. These were given in the form of a percentage of the total foraminiferal assemblage.

The results obtained were then considered in a number of different ways, in order to find the most convenient method of illustrating them.

a) Planktonic - Benthonic ratio. The graphical representation of the members of the superfamily *Globigerinacea* as a proportion of the foraminiferal assemblage has been much discussed, since its conception by Grimsdale and Morkhoven (1955). They outlined this ratio as a principle by which the depth of ancient seas could be calculated. Barr (1962) attempted to apply this method directly to the Upper Chalk of the Isle of Wight.

The results he obtained are interesting, but the present author feels that they could equally well reflect the type of samples collected, and the processing they required, rather than the depth of the Chalk sea. The same sort of comment may be levelled at the work of Flexer and Starinsky (1970), similar to that of Barr, examining the late Cretaceous chalks of northern Israel.

Doubts are therefore expressed regarding the use of this ratio, although other more stratigraphic applications are acknowledged. Hart, on several occasions (1973, 1975), has illustrated its value in the discussion of the mid-Cenomanian transgression of this country. He has also commented on its use "in the interpretation of Cretaceous palaeocurrent, palaeotemperature and palaeolatitude data" (Hart and Carter 1975).

The planktonic/benthonic ratio has had some limited value as part of the present study (Bailey 1975), and is therefore retained as part of the graphical illustrations. The reservation is expressed however, that lithological variations at specific horizons may affect the proportion of planktonic foraminifera to a limited extent. Thus only the general trends of this ratio are viewed with any degree of certainty.

b) Stratigraphic range charts and relative proportions.

The relative proportions of different species, expressed as percentages of the total assemblage, were illustrated in various ways, in the early part of this study. The majority of the more elaborate figures have since been discarded, as they were often difficult to construct. They also failed to clarify the results any better than the simpler methods finally used.

Superfamily percentage graphs, such as that figured by Hart and Carter (1975, text-fig. 6), give only broad and general information. For this reason, as the present work is seeking a more detailed zonation, this form of graph has not been used. When this form of graph is applied at the species level, and illustrated as a cumulative frequency polygon, it was found that the stratigraphically important, minor species could not be represented clearly enough. This is also the criticism of the form of relative percentage graphs used by Burnaby (1962) and Jefferies (1962).

Finally, the basic range chart proved its lasting value by clearly illustrating the zonation adopted in the present study. However, this was adapted by the addition of the relative proportion information, in the form of a histogram of variable width.

The width of the bar is proportional to the percentage of the represented species, within the total fauna of the sample. This mode of illustration has been of value on numerous occasions. Distinct trends within the relative proportions of individual species have been noted in the correlation of quite distant sections.

The basic form of range chart has been used for its species identified in the fine fractions, where these forms have been found to be useful as stratigraphic markers.

c) Assemblage zones. The zonal scheme finally adopted is based solely on the distribution of the benthonic foraminiferal fauna present in the succession studied. Theoretically this would appear to restrict its use to one of simple regional correlation. However, it is pointed out that many of the stratigraphically important groups in this part of the Upper Cretaceous, members of the genera *Stensioina* Brotzen *Gavelinella* Brotzen, *Neoflabellina* Bartenstein and *Reussella* Galloway, have geographical distributions covering much of northwestern Europe. The same groups have also been fully described as far south as the eastern coast of the Caspian Sea (Vasilenko 1961).

The details of the proposed zonation are given in the early part of Chapter 5, and thus provide the basic framework for the stratigraphy of the individual sections described.

d) Planktonic foraminiferal zonation. The proportion of planktonic foraminifera in the lower Senonian of southern England is relatively small, although enough exist to provide an indication of the stratigraphic position of the sections studied.

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The vertical distribution of the planktonic species described is discussed fully in Chapter 5, indicating the zonal value of each species. The sporadic occurrence of important species such as Globotruncana renzi (Gandolfi)and Globotruncana concavata Brotzen, is also discussed in the light of the work of Bolli (1959), Pessagno (1967) and van Hinte (1976).

2: 6 Microphotography and the Scanning Electron Microscope.

The use of the scanning electron microscope in Micropalaeontology has developed over the last decade, and is now well established. Like the processing of the original samples, the methods used to mount specimens for examination appear to be largely dependant on the individual carrying out the task.

It is for this reason that the method evolved during the course of this study is related here. In order that any future micropalaeontologist may avoid the mistakes made by the present author. The machine used throughout was the Cambridge S4-10 model, housed at the Royal Naval Engineering College, Plymouth. This was ideal for the work required.

The specially machined stubs used in this microscope were initially coated with double sided sellotape, and the specimens were, in turn, mounted onto this. The upper surface of the stub was then given a thin coating of gold, applied under a high vacuum. The recently developed "sputtering" technique, under a partial atmosphere of argon, was found to give the best results, leaving a thin veneer of 100 - 150 Å thickness.

Double sided sellotape was not considered to be the most successful base on which a continuous gold coat could be deposited, and an alternative was sought. Finch (1974) suggested the use of a black sealing wax, marketed as Apiezon W40, as a mounting medium.

This too was rejected as the wax had to be kept warm whilst the specimens were mounted, which is almost a practicable impossibility. It was also difficult to remove from perforate specimens after use, even with the addition of xylene as a solvent.

Finally the method of mounting specimens directly onto the stub, using "Kodaflat" gum, was acknowledged as being the easiest and most practical. This, in conjunction with the "sputterer" as a method of coating, was quite successful. Following this procedure the gold coating was continuous from specimen to stub surface and therefore no unwanted "charging" effects were created.

In order to photograph the specimen with its true dimensions the stub was positioned horizontally in the microscope chamber, instead of the more usual setting of 45° used for other work. This occasionally created a "shadowing" effect on a number of the more globular species, which was overcome by varying the voltage slightly, as the photograph was taken.

Despite the versatility and depth of focus achieved with a scanning electron microscope, the results obtained, with regard to some species of Foraminifera, are still not ideal. These species are identified by internal characters, such as the chamber arrangement. This type of feature is not available to a microscope which is only able to exhibit surface form and texture. For this reason, some groups have been illustrated with line drawings in the text, as well as being figured in the photographic plates.

CHAPTER 3.

DESCRIPTION OF LOCALITIES

The *Micraster* zones of southern England are well exposed in numerous places along the Channel coastline, and there are also many documented inland sections. Both types of exposure are described fully in Jukes - Browne and Hill (1904), and there are several later regional guides, including those of Osborne-White (1921, 1928) and Peake and Hancock (1961, 1970). Apart from these, and the extensive work of Rowe (1900-1908), which has already been discussed, there is a marked lack of detailed locality descriptions.

In a study which is intended to examine the lower Senonian Chalk of southern England, the list of localities which may be collected is, theoretically, quite extensive. It soon becomes apparent however, that a number of physical constraints are imposed on anyone wishing to sample this particular stratigraphic level.

The chalk of the *Micraster cortestudinarium* Zone has often been noted for its' hard, nodular appearance, principally caused by the presence of numerous indurated, incipient hardgrounds. It is because of this, and the relatively softer character of the chalk immediately above and below it, that this zone often forms prominent coastal head-lands. These, by nature, are often almost inaccessible, a problem typified by Ballard Point, at the northern end of Swanage Bay, and also by both the eastern and western extremities of the Isle of Wight.

The appearance of the nodular member of the pair is typically that of an incipient hardground (Kennedy and Garrison 1975). The limits of the bed are difficult to define as both horizons have been intenselybioturbated, prior to lithification and following the initial formation of the nodular fabric. Within this alternating system of incipient hardgrounds and soft white chalk, marl seams occur, along with thin,impersistant tabular flints and scattered nodular flints, the latter occasionally occurring as discernable burrow infillings.

Approximately 25 metres above the base of the section there is a prominent yellow horizon, selected by Rowe (1900) as the junction between the M. cortestudinarium and M. coranguinum Zones. Rowe also notes the presence of a distinct tabular flint, his "Micraster coranguinum tabular", 4 metres above the zonal boundary. This flint is of particular note, as it appears to be a little more consistant than the tabulars lower in the section. It is also unusual in that it truncates a number of large nodular flints, which occur in the bed immediately below it.

Above this marker the chalk apparently becomes "purer", as the nodular horizons, typical of the lower part of the section are absent. The succession was sampled for a further 16 metres, to the top of Langdon stairs, in order to provide a good overlap with the next accessible part of the section, at St. Margaret's Bay (TR 368 444).

The M. coranguinum Zone is fully exposed in the high cliffs on the north eastern side of the bay, a point noted by Osborne - White (1928). He suggested that this zone had a thickness in excess of 270 feet (82.35m), which is considered as a slight exageration as the cliffs at this locality have a maximum height of 257 feet (78.4m).

The hardness of the Chalk in the south western part of the country is also a limiting factor in the choice of sites for a micropalaeontological investigation. Several good exposures on the Dorset coastline have been so affected by structural deformation, that the processing techniques required destroy the total microfauna.

There are other problems encountered, including the infilling of old quarry sections, access to working quarries, and also two sections in restricted areas. For example, Arish Mell lies within a Royal Artillery firing range. All these limitations reduce the number of exposures which it is feasible to examine.

The successions used in the present study are believed to be representative of southern England. They have a wide geographical distribution, from Norfolk to Devon, and include major sections from south east Kent and the Isle of Wight.

The type of succession sampled is also variable. There are five coastal cliff sections, two of which are combinations of a number of smaller sequences. The samples from the Thames Barrier Site Investigation have been selected from three of the more important boreholes, and three quarries have been examined, one of which was still being worked.

Individual samples, not included in the sections described, have been used as comparative material from other areas. These have included Essex and Taplow in England, northern France and the island of Bornholm, Denmark. Material from the last two areas was collected by Dr. M.B. Hart, with the aid of a Scientific Investigation Grant provided by the Royal Society.

A lithological description of each of the sections studied follows:

3:1 South east Kent.

The lower Senonian chalk of south east Kent forms the renowned "white cliffs" between Dover and Walmer, and also around the southern and eastern side of the Isle of Thanet. The total thickness of the sequence studied in this area was 92 metres, although this overlapped across both the upper and lower limits of the Micraster zones. The thicknesses of the M. cortestudinarium Zone and the M. coranguinum Zone are recorded as 25.4 metres and 63 metres respectively, assessments which closely agree with those of Kennedy and Garrison (1975).

The cliffs of this coastline attain a maximum height of 76 metres at St. Margaret's Bay, where the M. coranguinum Zone is present in one vertical section (Text Pl. 1A), due to the sub-horizontal nature of the bedding. Access is difficult along this open cliff line and this in turn creates problems in correlating a complete section.

The dip of the bedding, around this coast, is rarely in excess of eight degrees. Therefore, by taking a series of overlapping sections and correlating between them, a composite succession may be drawn up. Seven sections were sampled and in all; one hundred and fifteen samples were collected and examined in compiling this sequence.

The lowest part of the succession is exposed in the sidewall of the zig-zag path, known as Langdon stairs (TR 346425), to the east of Dover Harbour. The path takes the form of six oblique levels which cut across the face of the cliff. Thus, by working up the path, samples can be taken regularly in the vertical southern faces.

The base of the present section was taken at the nodular hard-ground, present at the junction of the fifth and sixth levels of the path descending from the top of the cliff. Below this, much of the section is obscured by downfallen and overgrown debris, and further sampling would have been inaccurate. The base of the M. cortestudinarium Zone also falls in the vicinity of this junction (Rowe 1900, Osborne - White 1928), and it was at this level that Owen (1970) terminated his sampling of the Dover section, in his investigation of Turonian Foraminiferida.

The basal horizon is a yellowish - brown, nodular chalk, with pale creamy biomicritic nodules, surrounded by a greyer, marly calcarenite matrix. A few small flints are scattered through the unit. This is followed by a more uniform bed of creamy white chalk, approx-imately 0. 5 metres thick, with common marl dissolution seams. The two differing horizons form a distinct lithological pair which occur regularly, and almost rhythmically, for the next 16 metres, and then more irregularly for the following 12 metres.

A full collection of this zone was only achieved by traversing the four kilometres between St. Margaret's and Oldstairs Bay (TR 381 483), a section which is quite dangerous at any time after low tide. Small scale faults, with a throw of a few metres and low angle joints, such as those noted by Hancock (1976), occur along this algal covered section. However, with care, regular sampling was possible, through the 40 metres of the available succession.

This section reaches to "Bedwell's columnar flint", which is exposed in the small cliff behind the rifle range at Oldstairs Bay. Between this and the "coranguinum tabular" there are few useful lithological marker horizons. The chalk, where it is cleaned by wave action, is a pure white biomicrite, with distinct grey, marly horizons, normally seen as a complex mass of dissolution seams. There are also a few creamy-yellow horizons, which are possibly poorly developed nodular chalks, in association with flaser bedded marl bands.

Occasionally there is clear evidence of bioturbation, where an intermixing of white chalk and grey marlier sediment is present. Burrow flints, as described by Kennedy and Juignet (1974), are also common as distinctive horizons. Nodular flints are scattered throughout this section, although they are more restricted to specific levels, forming narrow flint bands.

"Bedwell's columnar flint" is a peculiar lithological feature which is easily recognised and therefore a useful marker horizon. It is formed by a horizontal band of large nodular flints, occasionally forming "columns" which rise vertically into the chalk above for over half a metre.

At this locality the higher part of the sequence is inaccessible, due to the nature of the cliffs, and, to the north, blown sand covering most of the section.

1A **The Chalk cliffs of St. Margarets' Bay, S.E Kent.**

A 70–80 metre high face, exposing the total thickness of the *M. coranguinum* Zone in Kent. "Whitakers' 3" tabular flint band" is visible towards the top of the cliff. Down fallen debris covers much of the section, but wave erosion at the cliff base makes the lower half of the zone accessible.

1B **"Whitakers' 3" tabular flint band", Joss Bay, Kent.**

A distinct lithological horizon, which lies close to a major faunal break. This continuous band of flint stretches for at least 25 kilometres around the south coast of Kent. The group of holes directly beneath the hammer, are the sites of short cores collected in conjunction with a palaeomagnetism research team from the University of Newcastle-upon-Tyne.

1A

1B

The beds, both above and below this horizon, are irregular and thicknesses of individual units are very inconsistant (Text Pl. 2A). Nodular flints are small and infrequent or totally absent and the sediment is extremely soft.

The upper limit of the section was taken at a further distinctive marker horizon present at this level. "Barrois" sponge bed (Text. Pl. 2B) was used by Rowe (1900) to define the top of the M. coranguinum Zone due to it's distinctive appearance and convenient stratigraphic position. It is a thin unit (0. 40m.) of creamy white chalk, rich in rusty brown, iron stained sponges, together with echinoid debris and crinoid ossicles.

Samples were taken both from this level, and the chalk above it for the next 3 metres, to complete the microfaunal succession into the Uintacrinus socialis Zone.

The photograph illustrating "Whitaker's 3 inch band" (Text. Pl.1b) also shows a series of small drill-holes, approximately 0. 5 metres below the flint. These samples were taken in conjunction with a geophysical investigation team from the University of Newcastle-upon-Tyne, who intended to examine any residual palaeomagnetism in the finer mineralogical content of the chalk. The palaeogeographic implications of such work are fairly obvious, but as the results of this preliminary investigation were totally inconclusive, nothing more can be added at present. However, new techniques now being investigated by the research team, led by Dr. D. M. Tarling, may allow more success in future work.

2A Variation in bed thickness, North Foreland, Kent.

In the upper part of the M. coranguinum Zone in Kent, flints are rare and the bedding becomes irregular. Small scale current scour features are present and low angle jointing is recorded (Hancock 1976).

2B "Barrois Sponge Bed" Joss Bay, Kent.

A distinct bed (immediately below the hammer) with abundant sponge remains, used as the upper limit of the M. coranguinum Zone in S. E. Kent. The bed is 0. 40 metres thick, and has an orange/brown staining, due to iron oxidation, possibly in association with the sponges.

2A

2B

Fortunately, lower Senonian chalk is encountered approximately 16 kilometres further north, around the eastern coast of the Isle of Thanet. The levels exposed at the top of the cliffs at Oldstairs Bay are present between Pegwell Bay and Margate, although the former provides a poor section which is largely inaccessible and covered by algae.

However, the succession is repeated to the north, due to the effect of a small normal fault at Dumpton Gap (TR396 667). "Bedwell's columnar flint" is accessible along this coast, and more clearly developed than to the south. The beds below it were again sampled, to give a good microfaunal overlap between the two sections. Impersistant tabular flints present in this part of the section give way to normal bands of nodular flints, which are extremely regular at this stratigraphic level.

The section collected was that between Joss Bay (TR402 700) and White Ness (TR 396 709), the sub-horizontal nature of the bedding making a continuous vertical succession impossible. Approximately 10 metres above the columnar flint, there outcrops an extremely persistant, thick tabular flint, referred to previously in the literature as "Whitaker's 3 inch band" (Text. Pl. 1B). The thickness of this unit is now recorded as 7 centimetres, and it's geographical extent is regarded as quite unique for a bed of this nature. It is present around much of the coast of Thanet and is also visible at the top of the cliffs above St. Margaret's Bay; the distance between the two is approximately 25 kilometres.

3:2 Thames Barrier Site Investigation.

The material used from the Thames Barrier Site Investigation (TQ 425 795), during this study, was derived from three of the main borehole sections (B.H. No. 25, B.H. No. 52 and B.H. No. 19). In the preliminary study. (Unpublished Report for Foundation Engineering Ltd.), Carter and Hart considered that the borehole section ranged between the _H. planus_ Zone through to the _U. socialis_ Zone. More recent work (Carter and Hart, in press A.) has confirmed the original zonation.

The longest of the three sections was provided by Borehole No.25 (South Bank), which was 99.25 metres deep. This, when combined with the upper part of Borehole No. 19 (mid-river), provided the full succession under investigation, a total thickness of 110 metres.

Only the lowest 16 metres of Borehole No. 52 (North Bank) were examined in detail. This section served as a useful correlation with the lower part of Borehole No. 25. It also acted as a cross-reference and test for the foraminiferal zonation used in the project.

A detailed lithological description is not available for the section, although notes provided by Mr. D. J. Carter, particularly regarding Borehole No. 25, give an outline of the lithologies encountered.

The basal 17 metres comprise soft, massive bioturbated chalk, with scattered marl dissolution seams, and numerous bands of nodular flints. Minor faulting is present at several points towards the base of the borehole, which was terminated in a distinctly nodular chalk.

Approximately 20 metres from the base marl seams become particularly abundant. A phosphatic nodular horizon occurs 22 metres above the base and bioturbated, soft, white chalk with scattered flint bands continues for the next 20 metres.

A concentration of flint bands is present above this, followed by massive white chalk with large burrows, infilled with darker, marly sediment.

Bioturbated chalk is recorded for the overlying 20 metres and above this, there is soft white chalk which is believed to be 'in situ'. The uppermost 5 metres of the section consists of soliflucted chalk, often with a superficial grey staining. This is overlain by 16 metres of more recent, loose soliflucted sediment.

3:3 The Isle of Wight

a) Freshwater Bay (SZ347 856). This embayment, at the western end of the island, cuts through the succession from the top of the *H. planus* Zone to the middle of the *U. socialis* Zone. This is possible, due to the steep inclination of the bedding, which has a dip of between 60 - 70 degrees to the north throughout the section.

Neither side of the bay is fully accessible except at an extremely low tide. However, by collecting the lower half of the succession on the western side of the bay and the upper half on the eastern side (Text. Pl. 3A) and correlating the two across, a full sequence may be compiled.

Although the junction of the *H. planus* and *M. cortestudinarium* Zones, used as the base of the present study, was sampled on the western side of the bay, it is better illustrated by its' eastern counterpart (Text. Pl. 4A). Rowe (1908) described it as two thin marl "approximately 1 foot 8 inches apart"; these can clearly be seen in the central part of the photograph.

The sediment at this level is well-bedded, with thick horizons of nodular chalk separated by thin marl seams, or distinct nodular flint bands set in a chalk matrix. Lithologically the chalk is a hard, recrystallisedcalcarenite, rich in marl which has undergone resolution during early diagenesis. Nodular chalks (Text. Pl.3B) are well developed, and incipient hardgrounds are present in the lower part of the M. cortestudinarium Zone. The fauna is quite rich throughout this zone, including numerous Micraster spp., Spondylus spinosus (Sowerby), Inoceramus spp., Porosphaera globularis (Phillips), and abundant broken shell debris.

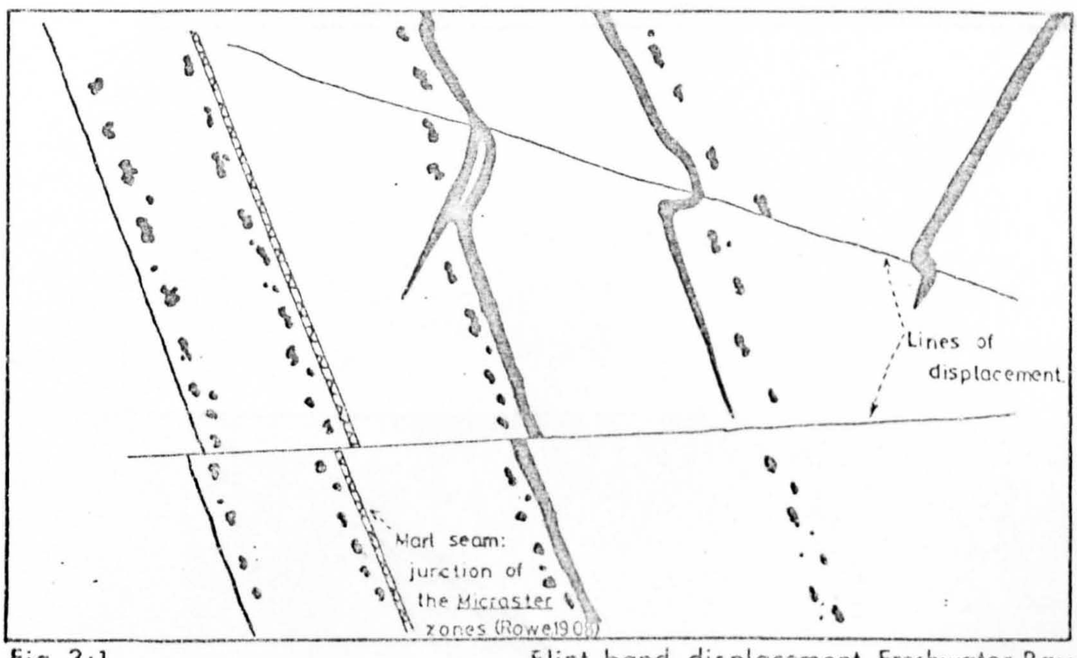
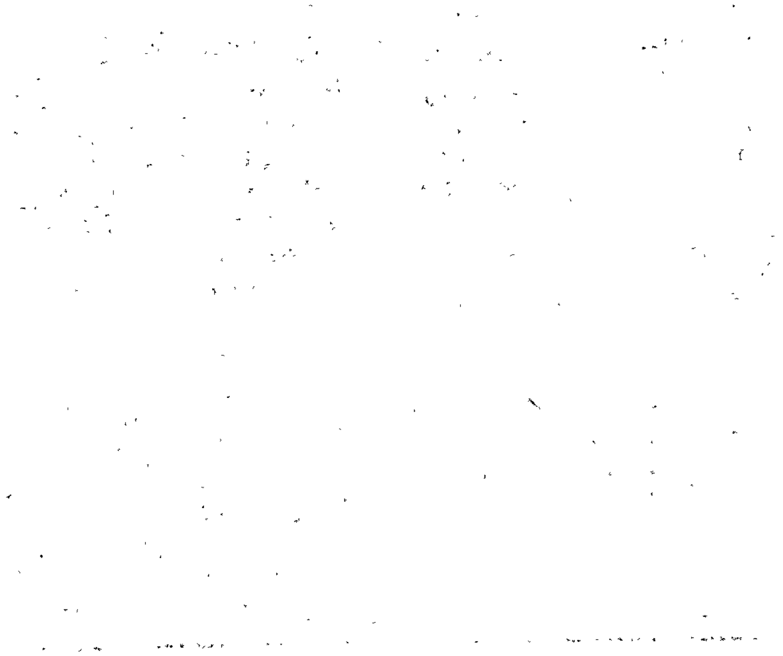
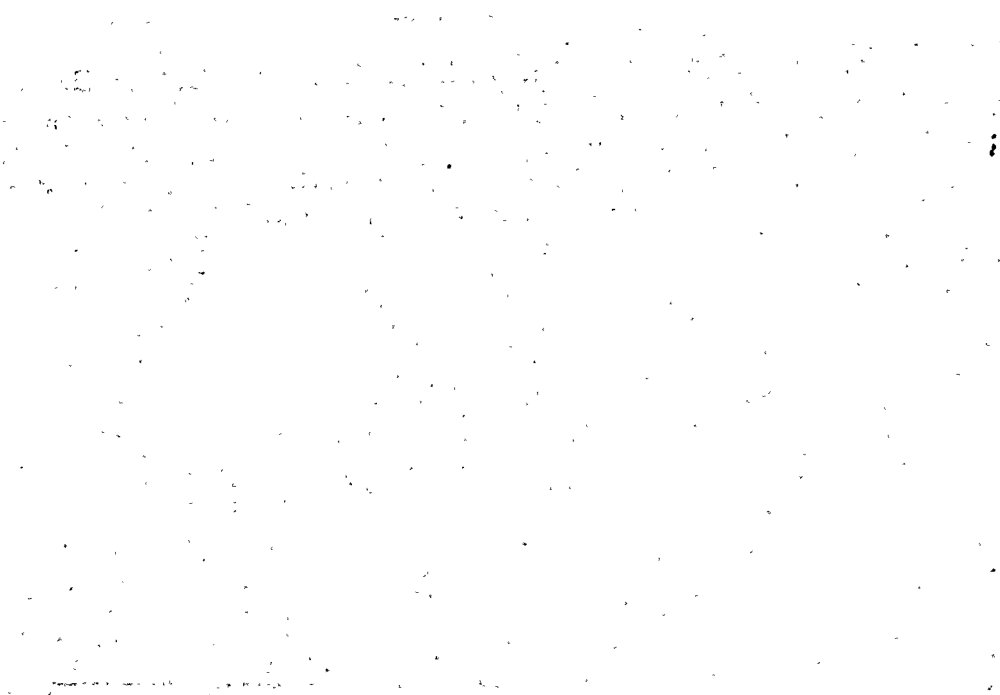


Fig. 3:1 Flint band displacement, Freshwater Bay

Regular bands of nodular flint occur frequently, and approximately 16 metres from the base of the section three thin tabular flints follow the bedding. This is not the case with the series of tabular flints developed two metres higher. These are parallel to the bedding for the most part, but displacement of the tabulars has taken place both during and after the formation of the flints (Fig.3:1). This has created both fracturing and arching in the veins of silica.





3A East side of Freshwater Bay, Isle of Wight.

A long section, with an average dip of around 60^{o}. Unfortunately most of the seaward side is inaccessible by foot, except at exceptional low tides. The junction between the M. cortestudinarium and M. coranguinum Zones crops out in the upper wall of the semi-circular cave seen at sea level.

3B Nodular chalk, M. cortestudinarium Zone, Freshwater Bay

Nodular chalks with a high proportion of marl are typical of the M. cortestudinarium Zone in the Isle of Wight. Some phosphatisation has occurred and marl seams act as bedding planes.

3A

3B

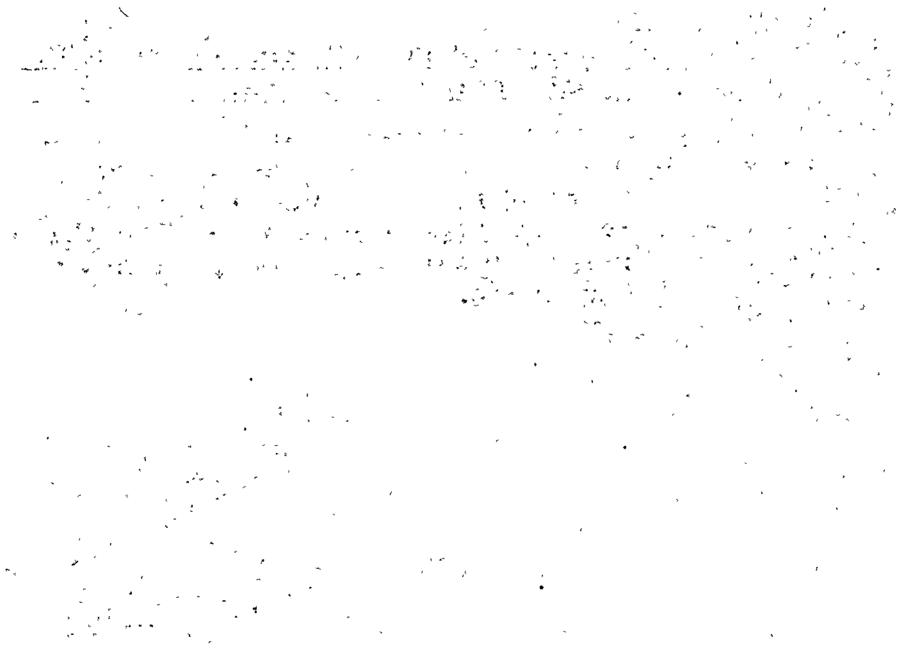
This feature lies just a metre above the M. cortestudinarium – M. coranguinum zonal boundary, as described by Rowe (1908), on the western side of the bay. The junction was also observed on the eastern side (Text. Pl. 4B) where the thin marl seam, used as the marker horizon, is visible in the roof of a large cave.

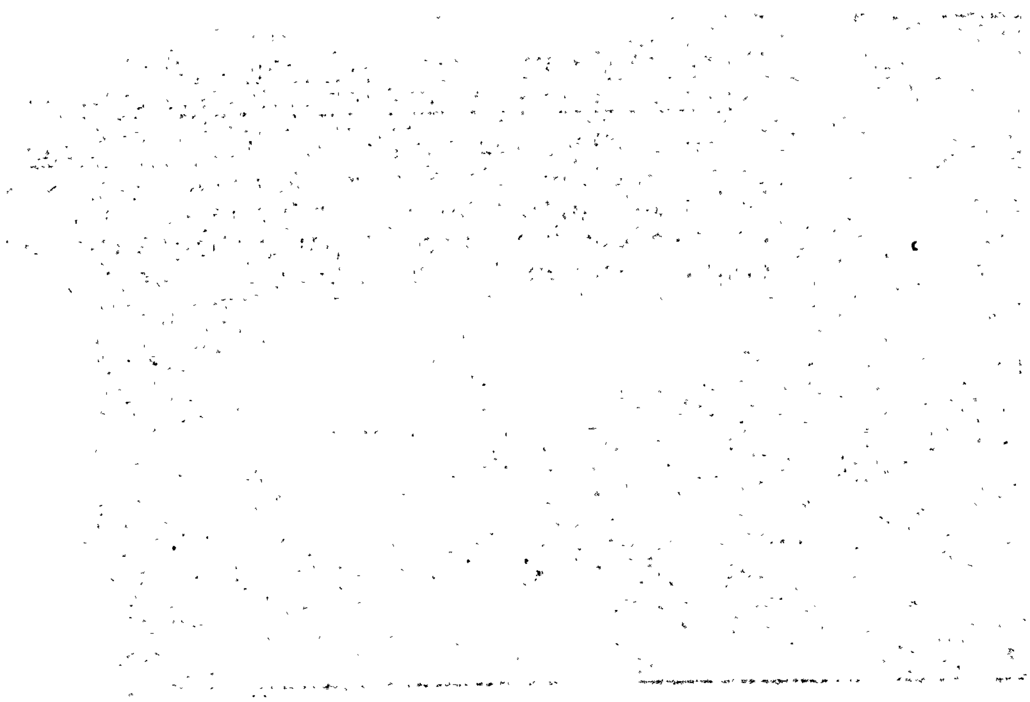
Above this boundary the rubbly, nodular chalk continues, with extremely frequent and regular nodular flint courses. As was the case in Kent, the chalk of the M. coranguinum Zone is slightly finer and softer than that of the zone below, and nodular horizons are much less frequent. The sediment at this level has a much more biomicritic, rather than calcarenitic texture, seen in the underlying nodular chalks.

Marl seams are quite common, weathering out to form narrow gaps between the thickly bedded chalk. Flaser structures are absent at this level, although small dissolution seams are normally present.

Approximately 21 metres above the zonal boundary the cliff on the western side of the bay becomes impossible to sample, due to downwashed debris and overgrowing vegetation. Fortunately, this level is accessible above the high tide mark on the eastern side and the section was continued there. The basal datum on this second leg of the sequence, was a thick black tabular flint, situated in the extreme eastern corner of the bay. Samples were taken below this line to provide an overlap with the western section and then continued upwards for a further 55 metres.

The rhythmic pattern of nodular flint horizons, set in a creamy chalk matrix, and creamy white flintless chalk is continued for the rest of the section. The sediment is a fine biomicrite, in which the macrofauna is poorly developed.





4A Holaster planus - Micraster cortestudinarium zonal junction, Freshwater Bay. Isle of Wight

The boundary between the two zones is taken at the two marl seams, half a metre apart, slightly to the left of the cave wall. Bands of nodular flints occur at regular intervals. These appear to follow distinct bedding horizons, often with evidence of burrowing.

4B Micraster contestudinarium - Micraster coranguinum zonal junction, Freshwater Bay, Isle of Wight.

Rowes' (1908) boundary between the Micraster zones is taken at the thin eroded marl seam, to the left of the photograph. Low angle minor faults and joints criss-cross the steeply dipping chalk. The nodular chalk is extremely indurated at this locality.

4A

4B

The zonal fossil, Micraster coranguinum Leske is not common, it does occur at scattered horizons. Other species found included Porosphaera globularis (Phillips), Glomerula gordialis (Schlotheim) ossicles of Bourgueticrinus sp. , bryozoans and sponge fragments, a few identified as Ventriculites sp. A thorough search was made for Uintacrinus socialis Grinnel, the basal occurrence of which is normally used as the upper limit of the M. coranguinum Zone, however this proved fruitless. Samples were taken to well above the level thought to be the zonal boundary to ensure that the complete succession was collected.

A total of 106 metres of chalk were examined, described and sampled at Freshwater Bay, which included the total thickness of both the Micraster zones.

b) Culver cliff (SZ 638 854). The accessibility of the cliffs at the eastern end of the island is an even greater problem than that encountered at Freshwater Bay. The beds of the Micraster zones can only be reached during a low tide, and collection of a full sequence is difficult. Despite this, the whole section was collected from the lower part of the M. cortestudinarium Zone, through to the U. socialis Zone. and in all 110 samples were taken from this succession.

Within the scope of the present study, only the uppermost 45 metres of the section have been fully examined. This covers what was believed to be the upper part of the M. coranguinum Zone, and the junction with the zone above, following Rowe's (1908) description. Brydone (1914) suggested that Rowe might have overestimated the thickness of the M. coranguinum Zone at Culver. A view endorsed by Osborne-White (1921) and further discussed by Barr (1962).

The stratigraphy of this section is reviewed in much greater detail in a later chapter, suffice it to say here that the microfauna provides additional information in the clarification of the problem.

Only a preliminary examination has been carried out on the lower part of the succession at this locality. The M. cortestudinarium Zone is characterised by the presence of indurated, creamy white, nodular chalks, which are developed into incipient hardgrounds at several levels. A few of these horizons are considered to be true hardgrounds as evidence of a boring infauna was noted. An abundant epifauna was accumulated on the upper surfaces of these phosphatic beds.

Nodular flint bands occur at regular intervals and persistant tabular flints are also common.

The base of the M. coranguinum Zone is drawn in the southern face of the northern "Nostril", one of the distinctive pair of caves present at the southern end of the section. The chalk, at this level, appears to be finer grained than that of the nodular beds of the zone below, and this smoother biomicritic texture continues throughout the rest of the section. The hard nature of the chalk persists for the whole of the section collected, this being due to the diagenetic changes imposed upon the sediment by later structural deformation.

Alternating bands of flintless white chalk and horizons rich in black nodular flints characterize the M. coranguinum Zone. Marl dissolution seams and tabular flints are present, but by no means common. The fauna is sparse, shell debris, is disseminated throughout the section, including large amounts of broken Inoceramus spp.

In the uppermost part of the section,bands of small, nodular flints are poorly developed and impersistant tabular flints are common. The chalk is a fine grained biomicrite, normally white, but with occasional yellowish,phosphatic horizons,and frequent rusty - brown patches, caused by the presence of oxidised iron compounds.

Minor faults were encountered in this section, and these were allowed for in the sampling intervals. The presence of downwashed and downfallen debris was not a major problem, as it seems to have been in the past (Rowe 1905, Osborne - White 1921).

3:4 Norfolk.

Two short sections were collected, for the author, by Mr. P. Weaver, and his help in drawing up the successions is acknowledged.

a) Newton-by-Castleacre (TF 836 150). This small quarry, which is no longer worked, was noted by Peake and Hancock (1961) as covering the junction of the *Micraster* Zones.

Approximately 1 metre of the lower part of the section was obscured by talus, although a clean sample was obtained below this. The rest of the section was continuous for 9 metres of soft, white, biomicritic chalk. Large nodular flints were found at seven distinct levels.

Two marly horizons occur in this section, the first at the top, consists of 10 centimetres of soft marly chalk. The second is 5.5 metres below this, forming a distinct marl seam 1 to 2 centimetres thick, underlain by 10 centimetres of marly chalk.

The lower marl was sampled and proved to be devoid of calcareous foraminifera.

The macrofauna was rare, and the samples yielded only echinoid and asteroid plates, a few fish teeth and broken Inoceramid prisms.

b) Helhoughton (TR 851 273) A 10 metre section, 11 kilometres to the north of Newton-by-Castleacre, containing chalk of the *M. cortestudinarium* Zone (Peake and Hancock 1961).

The chalk was of a similar character to that of the previous locality, although the upper part of the section was more weathered. The highest sample was a yellowish chalk rich in dendritic manganese. Very large, flat nodular flints were common throughout the section, and two thin impersistant tabular flints occurred, which migrated across the bedding.

A further sample was taken from a degraded section at Burnham Overy (TF 843 432), which is now thoroughly overgrown. This lies approximately 17 kilometres to the north of Helhoughton, and is recorded as yielding chalk from the *M. coranguinum* Zone (Peake & Hancock 1961).

3:5 Quidhampton, Wiltshire (SU 115 314)

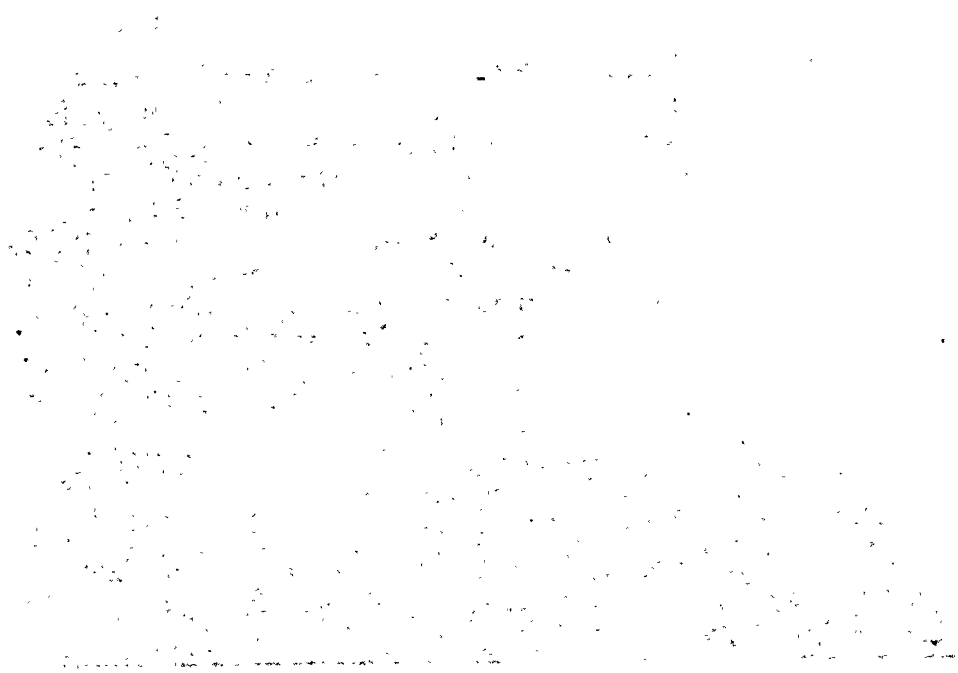
This large working quarry (Text. Pl.5A) was mentioned by Jukes - Browne and Hill (1904) as a small chalk pit in the *M. coranguinum* Zone.

The present author's attention was drawn to the value of the section by Mr. C. J. Wood (pers. comm.), who suggested that the relatively soft nature of the sediment would be ideal for a micropalaeontological examination.

The basal datum was taken at the lowest level of the quarry at the time of collection (January, 1976). The full succession of 28 metres was examined working up the succeeding levels, and correlating the short distances between sections lithologically.

The lower half of the section is characterised by the presence of numerous bands of flint of variable form. At 6 metres above the basal datum, large "paramoudra" like flints are common, and a further 2 metres above this several thin, impersistant tabular flints are present across the quarry face. In the upper half of the section only two persistant flint bands, are present, the lower is indistinct although a few nodules are as much as 0.5 metres across. The higher band however, is a prominent marker, 21.5 metres above the basal datum, formed by large, flattened, black nodules, which form an almost continuous tabular band.

The lithology of the chalk is consistant throughout the section. The rock is a "pure" fine grained biomicrite, white with occasional rusty brown iron stained horizons. These horizons are often associated with the presence of sponges, as is the case with "Barrois Sponge Bed" (Text. Pl. 2B) in Kent. A good specimen of M. coranguinum. Leske was found towards the top of the quarry and a large broken Inoceramus sp. was present 5 metres above the base. Otherwise the macrofauna noted was poor, probably as the locality is a working quarry, and all the faces were fresh.



5A Quidhampton Quarry, Salisbury, Wiltshire.

A 28 metre section of the M. coranguinum Zone is exposed in the succeeding levels of this quarry. The chalk is relatively soft and the higher levels almost devoid of flints.

5B Annis' Knob, Beer, South East Devon.

This section provides the most westerly accessible outcrop of chalk from the M. cortestudinarium Zone of southern England. Only the basal part of the zone is present, the junction with the H. planus Zone being taken at about the level of the distinct tabular flint, seen in the photograph approximately half way up the cliff face. The darker bands mark the levels of phosphatised incipient hardgrounds.

5A

5B

Periglacial activity has strongly affected the uppermost 6 to 8 metres of the section. Solution pipes, infilled with reddish - brown clay with flints,are common, and a few are quite extensive. This material also forms a thin veneer of overburden. The pipes were often large, in fact one had been excavated, by the quarry owners, to a depth of 15 metres, and the base was still not reached. Despite this, they had little affect on sampling as well bedded chalk was present through to the top of the quarry face.

3:6 Beer S.E. Devon (SY232 892)

The section at Annis' Knob (Text. Pl. 5B) has been described and discussed at some length by Rowe (1903) and Jukes-Browne and Hill (1904). A lithological description was given by Bailey (1975), but this is partly revised in this summary in the light of the subsequent work of Kennedy and Garrison (1975), in which the section is fully illustrated.

The Annis' Knob sequence is divided into three units, based on minor lithological variations (Bailey 1975). The lowest part of the cliff is formed by a nodular chalk with a high clay content in the form of dissolution seams. The base of the section is taken at a distinct nodular flint band at the foot of the cliff. This is immediately followed by a thick unit of nodular chalk with a strongly developed flaser structure, with nodular of creamy chalk enclosed in a grey marl matrix. Scattered flints occur through this unit which is capped by the distinct tabular flint, about half way up the cliff face (Text. Pl. 5B).

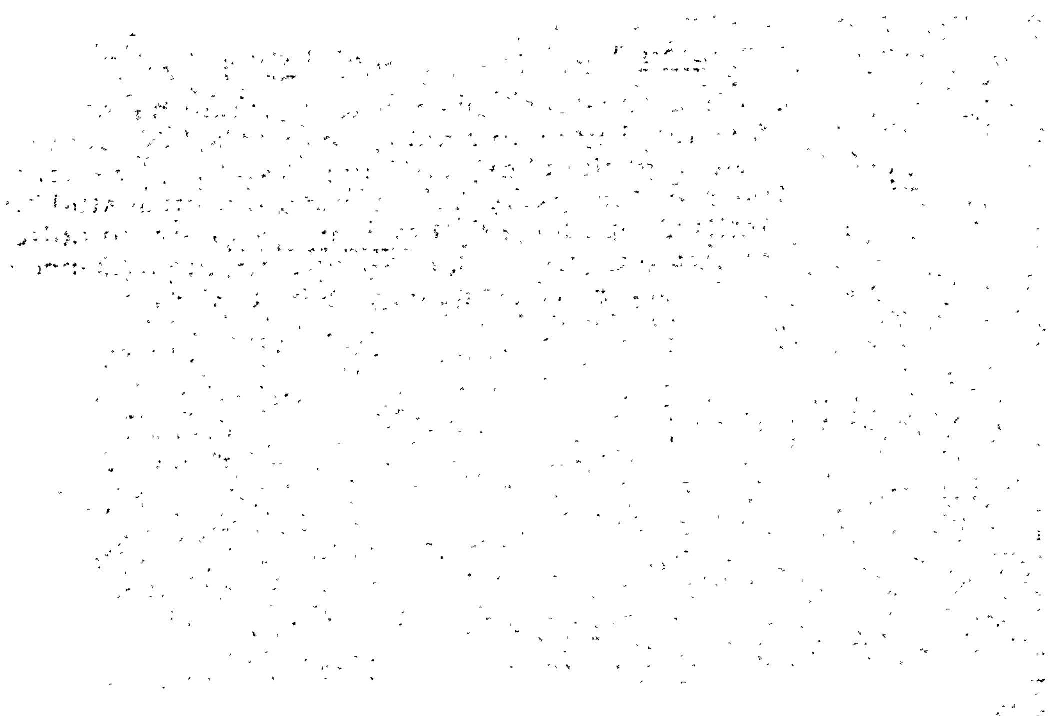
Above this flint is the second lithological unit, characterized by its nodular appearance and large number of incipient hardgrounds (Text. Pl. 6A). At least six of these occur in this unit, the typical form being illustrated in Text. Pl. 6B. The horizon is a deeper orange colour, when compared with the surrounding chalk, due to the abundance of phosphatised material. The "honeycomb" weathering is caused by the removal of softer chalk from around the indurated nodular material.

Bioturbation has destroyed any form of bedding, and the scattered flints tend to follow burrowed horizons. Dissolution marl seams are common, although not developed into the thicker marl bands seen elsewhere.

The presence of these indurated horizons at this level made micropalaeontological processing both unpractical and futile, so that an examination of thin-sectioned samples was carried out for much of this unit.

The third part of this section is a small 6 metre face, to the east of the main cliff, separated from it by a narrow belt of brecciated chalk. This, it is believed, represents a minor fault, the downthrow of which is difficult to determine, although it is probably only a matter of 10 to 20 metres to the east.

The base of this lithological unit is marked by an incipient hardground. Between this and the top of the section, which also has a pale yellow colouration (possibly due to phosphate content), the chalk has a fine smooth texture, lacking the nodular character of the open cliff. Large, scattered flint nodules occur through this part of the section and marl seams are quite common.

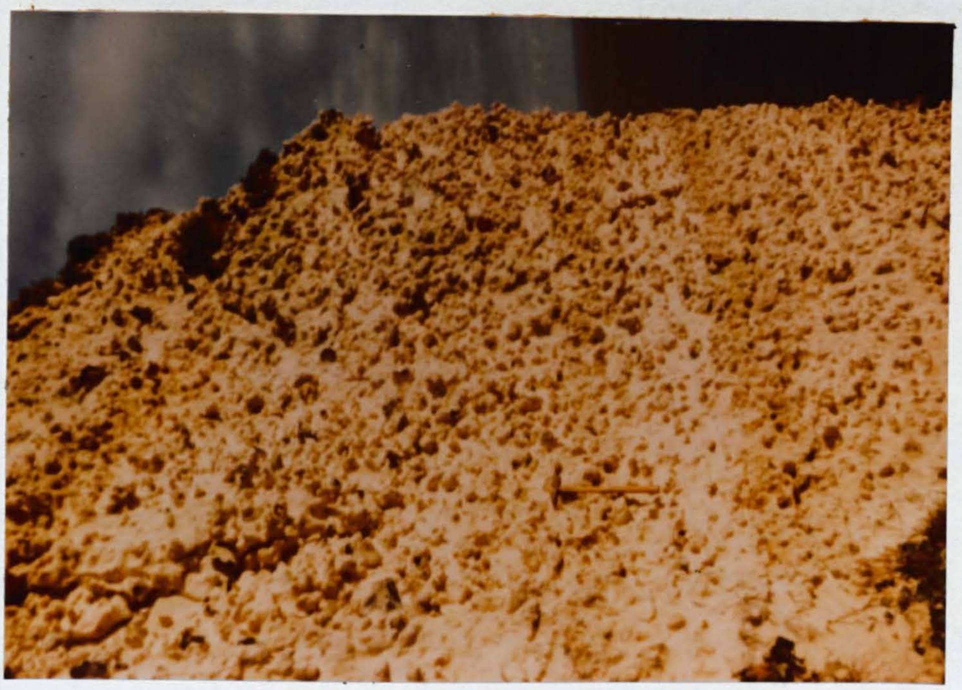


6A Incipient hardgrounds, Annis' Knob, Beer.

The extremely nodular chalk of the M. cortestudinarium Zone on the weathered cliff face. Incipient hardgrounds occur regularly through the section, traceable by their darker orange colouration. The hammer (shaft length approximately 0.30 metres) is resting across one of these horizons.

6B Incipient hardground, Annis' Knob, Beer.

This close-up of one of the incipient hardgrounds at this locality shows the characteristic orange/brown colour of the phosphatic horizon. Softer chalk has been eroded away from around the indurated burrows infills. Specimens of Micraster sp. were collected from the upper surface of this horizon. Burrow flints are common through the section.



6A

6B

3:7 Arish Mell, Dorset (SY 855 803).

A small 12 metre section was collected from the inside of a cave at the eastern end of the bay. The chalk of this area however, is so hard that it was of little value to process it except by taking a number of thin sections.

The macrofauna of this locality is reasonably abundant, probably due to the fact that few people have collected it since the Second World War, when the area was sealed off as a firing range for the Royal Artillery. The chalk of this bay would not suffer from a detailed palaeontological examination.

3:8 Summary

Kennedy and Garrison (1975) in their valuble work on nodular chalks and hardgrounds summarised the Upper Chalk as "a relatively monotonous sequence of bioturbated chalks with a non-calcareous fraction frequently less than 1%. Omission surfaces and flint bands, often associated with Thalassinoides systems, occur throughout, indicating that a rhythmicity comparable to that developed in the higher parts of the Middle Chalk is still present, although the homogeneity of much of the sequence makes interpretation difficult. There are, however, levels where cyclicity is strongly marked by the development of nodular chalks, incipient and true hardgrounds". From the preceding locality descriptions the validity of these comments can be judged, and little more can be added.

The stratigraphic details of each of the sections described have been kept to a minimum, and are more fully discussed later. The present chapter has been used merely to give some impression of the general character of the successions collected.

CHAPTER 4

SYSTEMATIC MICROPALAEONTOLOGY

The classification used in this account is based on that outlined by Loeblich and Tappan (1964) in the Treatise of Invertebrate Paleontology, part C Protista. In a few cases it has been amended in the light of more recently published information and conclusions drawn from the present study. These are discussed as and when they arise in the text.

During the course of this study 119 species and a further 8 varieties and subspecies, belonging to 52 different genera, have been recognised. Twenty one of these species are described for the first time, and many of the others are described fully for the first time from the British succession.

Comments regarding the evolutionary relationships and stratigraphic value of each species are included in the remarks following the species description, and discussion has been given at a generic level where this was thought necessary.

Order FORAMINIFERIDA Eichwald 1830

Suborder TEXTULARIINA Delage & Hérouard 1896

Superfamily AMMODISCACEA Reuss 1862

Family AMMODISCIDAE Reuss 1862

Subfamily AMMODISCINAE Reuss 1862

Genus AMMODISCUS Reuss 1862

Genotype Ammodiscus infimus Bornemann 1874

Ammodiscus cretaceus (Reuss) 1845

Pl. 1, fig. 1.

1845	Operculina cretacea	Reuss, p. 35, Pl. XIII, figs. 64, 65.
1860	Cornuspira "	(Reuss); Reuss, p. 177, Pl. 1, fig. 1a,b.
1899	" "	(Reuss); Egger, p. 18, Pl. 22, figs. 1, 2.
1925	" "	(Reuss); Franke, p. 7, Pl. 1, fig. 5.
1928	" "	(Reuss); Franke, p. 16, Pl. 1, fig. 22.
1929	" involvens	(Reuss); Berry & Kelley, p. 15, Pl. 1, fig. 15.
1934	Ammodiscus cretacea	(Reuss); Cushman, p. 45.
1941	" "	(Reuss); Marie, p. 18, Pl. 1, figs. 5, 6.
1946	" cretaceus	(Reuss); Cushman, p. 17, Pl. 1, fig. 35.
1953	" "	(Reuss); Hagn, p. 4, Pl. 1, fig. 3.
1954	" "	(Reuss); Frizzell, p. 58, Pl. 1, fig. 15.
1956	Involutina cretacea	(Reuss); Said & Kenawy, p. 120, Pl. 1, fig. 4.
1957	Ammodiscus cretaceous	(Reuss); McGugan, p. 336, Pl. 34, fig. 9.
1966	" cretaceus	(Reuss); Barr, p. 495, Pl. 77, fig. 2.

Test planispiral, closely coiled, very slightly involute; chamber increases uniformly in size through 5 to 6 whorls; suture distinct, depressed; wall very finely arenaceous; aperture simple opening at the end of the tube, formed by a single chamber, which is initially slightly inflated.

Maximum diameter: 0.78mm. Width. 0.12 mm.

Remarks: Slight variation is seen in the outline of the test, from circular to ovoid, in the latter form there is also a tendency for the later whorls to become more irregular in their direction of growth and the original planispiral habit may be distorted.

Range: Assemblage Zones A-F.

Superfamily LITUOLACEA de Blainville 1825

Family HORMOSINIDAE Haekel 1894

Subfamily HORMOSININAE Haekel 1894

Genus REOPHAX Montfort 1808

Genotype Reophax scorpiurus 1808

Reophax sp. A

Pl. 1, fig. 2.

Test free, small, sub-parallel sides, rounded at both ends; chambers difficult to distinguish, even when sections are made and the interval characters are visible; wall thick, finely arenaceous with calcareous cement; surface quite rough; aperture simple round hole in a terminal position.

Max. dimensions: Height 0.33 mm. Width 0.21 mm.

Remarks: This rather undistinguished species is not common, and is usually present in the $<$ 250 micron fraction, however larger specimens are found and even in these the chamber arrangement is obscure.

Range: Assemblage Zones A-E.

Family LITUOLIDAE de Blainville 1825

Subfamily LITUOLINAE de Blainville 1825

Genus AMMOBACULITES Cushman 1910

Genotype Spirolina agglutinans d'Orbigny

Ammobaculites sp. cf. A. rowei Barnard & Banner

Pl. 1, fig. 3.

1953 Ammobaculites rowei Barnard & Banner, p. 180, Pl. VII, fig. 6 A-C.

Test large and roughly triangular in outline; four chambers arranged in a planispiral coil, a fifth is missing, the last chamber is set at an angle to the previous group; chambers are sub-triangular to globular in shape, gradually increasing in size; sutures straight, distinct and slightly depressed; walls thick and extremely rugose formed by sub-angular quartz grains with calcareous cement. Simple round aperture centrally positioned.

Max. dimensions: Height 1.00 mm. Width 0.60 mm. Breadth 0.56 mm.

Remarks: Only one specimen of this species was encountered in the study. This was probably due to the harsh processing that much of the material required, which resulted in the breakage of the larger, more vulnerable species. Although this specimen is incomplete, when compared with the holotype, it was found to equate well with the initial portion of A. rowei; the rectilinear section being missing.

Range: Assemblage Zone A.

Family TEXTULARIIDAE Ehrenberg 1838

Subfamily SPIROPLECTAMMININAE Cushman 1927

Genus SPIROPLECTAMMINA Cushman 1927

Genotype Textularia agglutinans d'Orbigny var. biformis Parker & Jones 1865

Spiroplectammina anceps (Reuss) 1845
Pl. 1, figs. 4, 5.

1845	Textularia anceps	Reuss, p. 39, Pl. VIII, fig. 79, Pl. XLII, fig. 78.
1845	" praelonga	Reuss, p. 39, Pl. XII, fig. 14.
1899	" anceps	Reuss; Egger, p. 25, Pl. XXIV, figs. 35. 36
1928	Spiroplecta "	(Reuss); Franke, pp. 148-9, Pl. XIII, fig. 16.
1932	Spiroplectammina anceps	(Reuss); Cushman, p. 89, Pl. 11, figs. 5, 6.
1957	" laevis	(Roemer) var. cretosa Cushman; McGugan, p. 337, Pl. 34, fig. 8a, b.

Test free, elongate, compressed, widest point slightly above the mid-point of the test; margins acutely angled; initially planispiral, however this section is often missing or poorly preserved, biserial for the length of the test; chambers indistinct, flattened, oblique, slightly overlapping; sutures flush with surface, oblique, straight, to slightly curved towards the margins; wall finely arenaceous with a calcareous cement; aperture small slit on the inner margin of the final chamber.
Max. dimensions: Length 0.68 mm. Width 0.23 mm.
Remarks: This species is slightly tapered at both ends when later stages are present. In the majority of the specimens encountered however, this tapering at the apertural end was not seen, presumably because these were juvenile forms.

Some confusion exists between the profusion of species names for Upper Cretaceous members of this genus. Cushman (1932) attempted to clarify the situation, and stated that after careful examination of type specimens, and much topotypic material, S. anceps (Reuss) is a distinct species. He also noted from Reuss's original material that "Textularia praelonga Reuss" is in fact the gerontic stage of S.anceps.

A trivial name which has been used consistently for closely related American forms is S. semicomplanata (Carsey), and it is thought that the present species and its American counterpart may be synonymous. However, the earlier, European name has been retained, despite the poor nature of the original figures and description.

Range: Assemblage Zones A-F.

Subfamily: TEXTULARIINAE Ehrenberg 1838

Genus BIGENERINA d'Orbigny 1826.

Genotype Bigenerina nodosaria Cushman 1911.

Bigenerina sp. A

Pl. 1, fig. 6.

Test free, elongate, early portion biserial, broken in the majority of the specimens examined; chambers elongate becoming cylinderical in the later stages; sutures oblique initially becoming straight, slightly depressed; wall finely arenaceous with a calcareous cement; aperture simple, terminal.

Max. dimensions: Length 0.65 mm. Width 0.22 mm.

Remarks: The chamber arrangement is similar to that of Bigenerina cretae described by Ehrenberg (1854) from the Chalk at Gravesend, Kent. Unfortunately, he does not give a description and his only diagram is one of a sectioned specimen. The present species cannot be assigned to Ehrenbergs' species with such a limited amount of information.

Range: Assemblage Zones A-D.

Family ATAXOPHRAGMIIDAE Schwager 1877

Subfamily VERNEUILININAE Cushman 1911

Genus VERNEUILINA d'Orbigny 1839

Genotype Verneuilina tricarinata d'Orbigny

Verneuilina münsteri Reuss 1854

Pl. 1, fig. 7.

1845 Textularia triquetra (v. Munstr.); Reuss, p. 39.

1854 Verneulina münsteri Reuss, Reuss, p. 71. Pl. 26, fig. 5.

1936 " limbata Cushman, p. 2, Pl. 1, fig. 2.

1937 " " Cushman; Cushman, p. 12. Pl. 1, fig. 21.

1957 " " Cushman; McGugan, p. 337, Pl. 34, figs. 4-7.

1961 " münsteri (Reuss); Vasilenko, p. 15, Pl. 1. fig. 8a-c.

1975 " " (Reuss); Robaszynski, in Colbeaux et al, p. 19. fig. 2.

Test elongate, triangular in section, increasing uniformly and rapidly in size; sides flat to slightly concave; chambers distinct; sutures flush to slightly raised, strongly curved; wall finely arenaceous with calcareous cement, smooth; aperture sharp loop shaped opening towards the centre of the inner margin of the apertural face.

Max. dimensions: Height 1.25mm. Width 0.65 mm.

Remarks: The specimens examined in this study are thought to resemble more closely those figured by Cushman (1936) as V. limbata than the original figures of V. münsteri (Reuss), although the two share several specific characters. However, the trivial name of V. limbata had already been occupied by Terquem (1882) in his discussion of the Eocene Foraminifera of the Paris Basin, making V. limbata Cushman a junior homonym, and therefore invalid.

The specific name V. münsteri (Reuss) has subsequently been adopted for this group following the example set by Vasilenko (1961) and Robaszynski (1975, pers. comm).

This species is distinct from V. tricarinata (d'Orbigny) in having sutures which are more markedly limbate.

The ranges of the two species closely overlap and it is believed that there may be a considerable amount of confusion in early literature.

The majority of the specimens show the distinct triserial chamber arrangement throughout their growth. However, in a few specimens, there is a tendency towards a biserial pattern in the final few chambers. This feature casts some doubt on the generic position of the group and is therefore discussed more fully below.

Range: Assemblage Zones A-F.

Verneuilina sp. A

Pl. 1, fig. 8.

Test triserial throughout, increasing uniformly in size; sides flat in initial chambers, beginning to flare more widely later; edges rounded becoming almost lobate in later chambers; chambers distinct; sutures curved slightly and depressed; wall quite coarsely arenaceous with calcareous cement; aperture simple semi-circular hole in the inner margin of the apertural face.

Max. dimensions: Height 0.56 mm. Width 0.38 mm.

Remarks: Similar to V. münsteri (Reuss), but distinguished by the more rugose appearance of the wall and by having depressed sutures. Here again there is a possible tendency to become biserial in a few larger individuals.

Range: Assemblage Zones A-E.

Genus GAUDRYINA d'Orbigny 1839

Genotype Gaudryina rugosa d'Orbigny 1840

Gaudryina frankei Brotzen 1936

Pl. 1, fig. 9.

1936 Gaudryina frankei Brotzen, p. 33, Pl. 1, fig. 7a,b, p. 34, t. fig. 5.

Test triserial in initial stages becoming distinctly biserial for the later two-thirds of the shell, broadly wedge-shaped, becoming sub-parallel, quadrilaterial appearance in transverse section; walls flat to slightly concave; edges rounded, indistinct in later chambers; chambers poorly visible in triserial section, distinct, becoming slightly inflated in the triserial portion; sutures straight, depressed; wall quite finely arenaceous with calcareous cement; aperture simple towards centre of the final suture.

Max. dimensions: Height 0.61 mm. Width 0.38 mm.

Remarks: G. frankei Brotzen differs from G. rugosa d'Orbigny in that the latter is much more ovoid in transverse section in the adult form. G. rugosa also tends to be more slender in overall appearance. G. laevigata Franke is another closely related form in which the triserial portion is much shorter than that of G. frankei.

Range: Upper part of Assemblage Zone A – Assemblage Zone F.

Gaudryina jonesiana Wright 1886

Pl. 1, fig. 10.

1886 Gaudryina jonesiana Wright, p. 329, Pl. 27, figs. 1-2.

1914 " carinata Franke, p. 431, Pl. 27, figs. 4-6.

1928 " " Franke; Franke, p. 144, Pl. XIII, fig. 10a-c.

1936 " " Franke; Brotzen, p. 35, Pl. 1, figs. 5a-c.

1937 " (Siphogaudryina) jonesiana Wright; Cushman, pp 75-6, Pl. 1, figs. 7-10.

Test elongate, tapering rapidly at the base, sub-parallel for much of its length; triserial portion short, biserial portion compressed, quadrilateral in transverse section; edges of early portion sharp to carinate, faces flat or slightly concave; biserial portion distinctly carinate on all four edges, carinae of frontal face tend to fuse to form that of the triserial portion; faces flat to concave; chambers fairly distinct; sutures straight to slightly curved, flush with surface; wall finely arenaceous with calcareous cement; aperture interomarginal, simple in centre of final suture.

Max. dimensions: Height 0.63 mm. Width 0.30 mm.

Remarks: The original figures of G. jonesiana Wright are somewhat stylised, as are Frankes' (1928) figures of G. carinata. The original plates of this later species are recognisable but unfortunately out of focus. These factors being considered the present author believes that both Wright and Franke were describing the same species. Gaudryina stephensoni Cushman, a form described from the Upper Cretaceous of Texas, is also believed to be a closely related species.

Range: Assemblage Zones A-F.

THE TAXONOMIC POSITION OF THE GENERA VERNEUILINA AND GAUDRYINA.

The essential difference between the two genera is the fact that the latter becomes biserial after an initial triserial phase, whereas the former retains its' triserial chamber arrangement throughout.

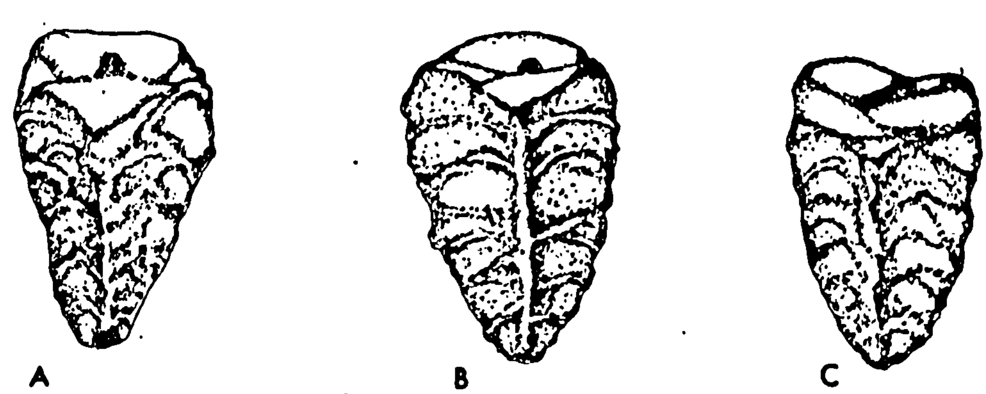
During the course of this study, of the large number of V. münsteri recorded, the majority display the above generic character. However, in occasional larger, and therefore more gerontic forms, the tendency to acquire a biserial mode of growth has been noted. Thus, the situation arises where a specimen with all the characters of V. münsteri for the larger part of its test gains the diagnostic feature of a Gaudryina.

This problem has been noted in the past particularly by Loeblich & Tappan (1964) in a discussion on generic variability within the subfamily Verneuilininae. They note that "All specimens of Verneuilina bronni illustrated by Reuss (1846), Cushman (1937) and others show typical characters of Gaudryina". However they also state that "The characters shown by the major part of the species population must determine the generic placement".

For this reason alone the genus Verneuilina remains a viable taxon, in that by far the larger part of the population studied exhibits a distinct triserial chamber arrangement. In fig.4:1 this situation is illustrated by three individuals of the species V. münsteri (Reuss). Specimen A is the typical form of the species; specimen B is a more transitional form through to specimen C, which, if considered on its' individual characters, would fall within the bounds of the genus Gaudryina.

It is believed that the "adult" form of Verneuilina is in fact biserial in its' later stages. However, reproduction and the subsequent rejection of the test may frequently take place before this biserial chamber arrangement is attained.

Fig.4:1



Morphological variation in Verneuilina münsteri

Genus TRITAXIA Reuss 1860

Genotype *Textularia tricarinata* Reuss 1844

Tritaxia tricarinata (Reuss)

Pl. 1 figs. 11 & 12.

1844	*Textularia tricarinata*	Reuss, p. 215.
1845	" "	Reuss; Reuss, p. 39, Pl. VIII, fig. 60.
1851	*Verneuilina dubia*	Reuss, p. 40, Pl. IV. (V), fig. 3.
1860	*Tritaxia tricarinata*	(Reuss); Reuss, p. 228, Pl. XII, figs. 1, 2.
1928	*Clavulina angularis*	Franke (non d'Orbigny), p. 140, Pl. XIII, fig. 1.
1928	*Tritaxia tricarinata*	(Reuss); Franke, p. 137, Pl. XII, fig. 17..
1937	" *dubia*	(Reuss); Cushman, p. 26, Pl. 4, figs. 1-4.
1937	" *tricarinata*	(Reuss); Cushman, p. 25, Pl. 3, figs. 16-25.
1949	" "	(Reuss); Cuvillier & Szakall, p. 20, Pl. 7, fig. 7.
1953	" "	(Reuss); Barnard & Banner, p. 193, Pl. VIII, fig. 1, A-E, t. fig. 3, A-J.
1957	" "	(Reuss); Hofker, p. 67, t. fig. 67.
1957	" *dubia*	(Reuss); Hofker, p. 67, t. figs. 68-9.
1966	" *tricarinata*	(Reuss); Butt, p. 171, Pl. 1, fig. 1.

Test free, extremely variable in shape between the typical sub-triangular ovoid form to the narrower, more elongate sub-parallel variety; transverse section distinctly triangular with rounded, sub-angular edges; chamber arrangement triserial for the whole length of the test except in a small number of individuals which take on a uniserial habit in the adult stages; sutures indistinct; wall arenaceous, usually smooth, however some variation towards a coarser appearance; centrally positioned, simple terminal aperture in uniserial forms, tending to be towards the inner edge of the final chamber in those forms which are still triserial.

Max. dimensions: Typical form - Height 0.54 mm. Width 0.38 mm.
Elongate form - Height 0.96 mm. Width 0.45 mm.

Remarks: This species exhibits an unusually large range of variation, and a case could possibly be made for the two extreme forms to be placed in distinct taxa, as there does appear to be a slight difference in their respective stratigraphical ranges, the shorter, wider form appears as early as the late Cenomanian and persists through to the lower Santonian, whereas the elongate variety is more characteristic of the Late Turonian to Santonian interval. However, it should be noted that Banner (Barnard & Banner, 1953) in a lengthy description of the species, figured a complete gradation between the members. Examination of those specimens (B.M. No. P41224) has confirmed the presence of a single, widely variable group, where the variation in shape may be of little, or no evolutionary significance.

Range: Assemblage Zones A-F.

Subfamily GLOBOTEXTULARIINAE Cushman 1927

Genus ARENOBULIMINA Cushman 1927

Genotype Bulimina presli Reuss 1846

Arenobulimina courta (Marie) 1941
Pl. 1, fig. 13.

1851 ?Bulimina obesa Reuss, p. 40, Pl. 4, fig. 12 only.

1941 Hagenowella courta Marie, p. 43, Pl. 7, figs. 68 a,b.

1953 " " Marie; Barnard & Banner, p. 202, t. fig. 6 J-O.

Test free, globular, slightly conical, initial chambers forming an obtuse angle at the base of the spire; chambers slightly inflated, more so in the final whorl occupied by four globular chambers which make up about two-thirds of the test;

sutures set in distinct depressions; wall thick, finely arenaceous although a few specimens do appear to be formed by a coarser grain size; aperture, a simple slit-like opening situated on the interomarginal suture of the final chamber, commencing at the angle formed at the junction of all three sutures in final whorl.

Max. dimensions: Height 0.40 mm. Width 0.66 mm.

Remarks: This common species was originally described from the Belemnitella mucronata Zone of the Paris Basin by Marie (1941). He referred it to the genus Hagenowella Cushman, which has since been discarded (Loeblich & Tappan 1961, 1964) on the grounds that the genotype (Valvulina gibbosa d'Orbigny) has a simple interior, compared with internal radial partitions characteristic of the genus Hagenowina Loeblich & Tappan 1961. The population present in the lower Senonian of this country has a simple interior and therefore falls within the scope of the Arenobulimina genus, as suggested by Loeblich and Tappan.

Range: Assemblage Zones A-F.

Arenobulimina sp. cf. A. polonica Gawor-Biedowa 1969
Pl. 1, fig. 14.

1969 Arenobulimina polonica Gawor-Biedowa, pp. 90-93, Pl. VIII, figs. 5a,b, figs. 6-8, T. figs. 9,10.

Test free, elongate trochospiral, wedge shaped but with a distinctly sub-parallel outline, length equal to twice the width at its broadest point, that of the youngest whorl, chambers elongate arranged obliquely about the axis of the trochospire; sutures oblique and slightly depressed; wall thick, finely arenaceous giving a smooth surface; aperture formed by a wide arcuate slit, situated on the internal margin of the final reniform chamber.

Max. dimensions: Height 1.24 mm. Width 0.53 mm.

Remarks: Gawor-Biedowa records Arenobulimina polonica as being common in Lower Cenomanian borehole material from western Poland, and the present author is unable to record any mention of the species from younger deposits.

However, throughout the present study, specimens have been examined which bear marked similarities to the form under discussion, and it is believed that these may be a continuation of an evolutionary lineage stemming from the Cenomanian.

Range: Assemblage Zones A-F.

Arenobulimina pseudorbignyi Marie 1941

T. fig. 4:2.

1937 Arenobulimina d'Orbignyi Marie, p. 261.

1941 " pseudorbignyi Marie, p. 50, Pl. IV, fig. 37 a-e.

Test free, trochospiral, rapidly expanding, maximum width below final chamber; reniform chambers, oblique, slightly inflated; sutures flush to slightly depressed; wall thick, rugose, coarsely arenaceous; aperture simple arch, on inner margin of final chamber.

Max. dimensions: Height 0.93 mm. Width 0.57 mm.

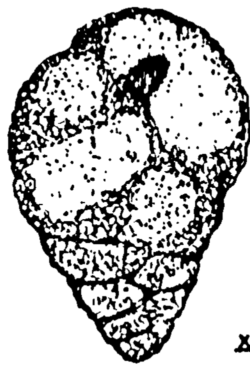
Remarks: The rest shows a marked similarity with that of A. obliqua (d'Orbigny) with which it may be confused. The overall shape is that of A. obliqua, including such features as the chamber arrangement and the uniform increase in size. Maries' type figures even go as far as to show A. pseudorbignyi with a final reniform chamber clearly overlapping onto the previous whorl, although it has been found that this is not always the case. The overlap is not as distinct as that of A. obliqua.

The most important, distinguishing feature of the species is the extremely rugose nature of the wall, being formed with coarse arenaceous material with a calcareous cement. Marie records the presence of internal partitions, which are better developed in earlier Turonian specimens and somewhat reduced in later forms.

Those from the lower Senonian of southern England tend to have simple interiors, but this feature is not thought to affect their specific position. Arenobulimina pseudorbignyi is also larger and more robust.

Range: Assemblage Zone C.

Fig. 4:2
Arenobulimina pseudorbignyi


x50

Arenobulimina obliqua (d'Orbigny) 1840 sensu lata

Pl. 1. fig. 15.

1840 Bulimina obliqua d'Orbigny, p. 40, Pl. IV, figs. 7, 8.

1928 " " d'Orbigny; Franke, p. 156, Pl. XIV, fig. 11ab.

1934 Arenobulimina obliqua (d'Orbigny); Cushman & Parker, p. 28. Pl. 5, figs. 5, 6.

1937 Bulimina obliqua d'Orbigny; Marie, p. 261.

1941 Arenobulimina obliqua (d'Orbigny); Marie, pp. 47-8, Pl. IV, fig. 34 a-f.

Test variable, cone-shaped trochospire, greatest width across final chamber; apical angle approximately 40°, expanding rapidly; reniform chambers, arranged obliquely, large and slightly inflated, final chamber becoming lobate, strongly overlapping the previous whorl; sutures slightly depressed, obliques; wall thick, finely arenaceous occasionally becoming more rugose; chambers internally simple lacking any partitions; aperture interomariginal arch variable to a crescentic loop, relatively simple.

Max. dimensions: Height 0.92 mm. Width 0.64 mm.

Remarks: The great variation present within this species possibly originates with d'Orbignys' original figures, which are grossly stylised, and lack essential features. However, two important characters are present in these diagrams which are of note, namely, the distinctive overlap of the final chamber onto the previous whorl and the sharp conical trochospire. The latter was possibly overemphasised by the artist. These two characters are diagnostic at the species level.

Cushman & Parker (1934) figure what is referred to as "practically topotype material" from the Craie Blanche of Bougival, France, and ascertain that the species is definitely arenaceous. Their figured specimen has a greater apical angle than that of the type figures, but, as suggested above this was to be expected. The specimen figured by Cushman and Parker is typical of those found in the lower Senonian of southern England, allowing for some variation within the population. They also suggest that the species "Bulimina preslii" Reuss should be referred to as A. obliqua when recorded from the upper Senonian, Reuss' species being more typical of the Turonian and lower Senonian. It is therefore possible that the present author may have included individuals, referable to A. preslii (Reuss) by others, within the broad scope of the present species.

Range: Assemblage Zones A-F.

Arenobulimina sp. A.

Pl. 1, fig. 16.

Test elongate, ovoid, with distinctly sub-parallel sides, rapidly expanding from the initial chambers forming a very obtuse apical angle which is often rounded; three to four whorls of indistinct, oblique, chambers, slightly inflated, with simple interiors;

sutures flush with the surface and difficult to define; wall thick, finely arenaceous with abundant cement; aperture normally quite large, semi-circular hole situated on the inner margin of the reniform final chamber, almost totally surrounded by the lobes of this chamber.

Max. dimensions: Height 0.61 mm. Width 0.32 mm.

Remarks: The author has been unable to locate any descriptions of the genus Arenobulimina which make any reference to forms similar to the species under discussion. The elongate, sub-parallel nature of the test outline is similar to that noted in Arenobulimina polonica Gawor-Biedowa. This species however, has a much more acute apical angle, and achieves a maximum width more rapidly than does A.polonica.

The apertural surface, viewed from above, normally shows an arrangement of four chambers in the final whorl similar to that shown by members of the genus Hagenowina. The present species, with its' simple internal chamber walls, is firmly placed within the Arenobulimina group.

Range: Assemblage Zones C-E.

Genus DOROTHIA Plummer 1931.

Genotype Gaudryina bulletta Carsey 1926

Dorothia pupa (Reuss) 1860.

Pl. 2, fig. 1.

1860 Textilaria pupa Reuss, p. 232, Pl. XIV, figs. 4,5.

1870 Gaudryina crassa Karrer, p. 166, Pl. 1 (X), fig. 4.

1925 " pupoides d'Orbigny; Franke, p. 41, Pl. 1, fig. 26ab.

1928 " " d'Orbigny; Franke, p. 143, Pl. XIII, fig. 7a,b.

1931 " " d'Orbigny; Cushman, p. 301, Pl. 34, fig. 6.

1937 Dorothia pupa (Reuss); Cushman, p. 78, Pl. 8, figs. 22,24a,b.

1937 Gaudryina pupoides d'Orbigny; Marie, p. 261.

1941 " cf. pupoides d'Orbigny; Marie, p. 65, Pl. III, figs. 24-27.

1941 " gradata Berthelin var, crassa Marie; Marie, p. 66, Pl. III, figs. 29a-c.

1953 Dorothia pupa (Reuss); Banner, in Barnard & Banner, p. 191, Pl. VIII, fig. 3, t, figs, 2i & 4B, E.

Test conical, trochoid initially, becoming biserial later, circular in cross-section in early stages becoming more ovoid in the adult stages; initial whorl with four or more chambers followed by two to three rapidly expanding whorls, in a trochoid arrangement, this is followed by a series of biserial chambers which are inflated and slightly overlapping; sutures slightly depressed throughout, notably concave in the biserial portion; walls finely arenaceous, with abundant calcareous cement, normally smooth but some individuals may be more rugose; aperture situated along the inner margin of the final chamber, slit-like to semi-circular in shape.

Max. dimensions: Height 0.53 mm. Width 0.40 mm.

Remarks: Banner (Barnard & Banner 1953) in a lengthy discussion of the genus Dorothia outlines the major problems which have arisen following Plummers' (1931) original generic description, and he noted "that the generic status of Dorothia Plummer may be doubtful". The source of the confusion is the nature of the initial whorl, which although described by Plummer as "composed of more than three chambers" is extremely variable between the megalo- and microspheric stages, and is frequently indistinct. Loeblich & Tappan (1964) maintain that Dorothia should remain separate from Gaudryina, with the number of chambers in the first whorl, being the dividing factor. The early stage of Gaudryina is triserial whereas that of Dorothia has "four or more chambers".

Specimens have been compared with those of Barnard & Banner (1953), (B.M. No. P41218), and were found to equate well with their specimens of D. pupa (Reuss). This species is very similar to D. bulletta (Carsey) described from the upper Cretaceous of Texas. In Reuss' original diagrams of D. pupa however, the sutures are very depressed whereas those of D. bulletta are much less so, and the two are therefore considered separate species.

Range: Upper part of Assemblage Zones A - Assemblage Zone F.

Genus MARSSONELLA Cushman 1933

Genotype Gaudryina oxycona Reuss 1860

Marssonella oxycona (Reuss) 1860

Pl. 2, fig. 2.

1860	Gaudryina oxycona	Reuss, p. 229, Pl. 12, fig. 3.
1899	" "	Reuss; Egger, p. 38, Pl. 4, figs, 1-3.
1925	" "	Reuss; Franke, p. 15, Pl. 1, figs. 20a,b.
1928	" "	Reuss; Franke, p. 143, Pl. 13, figs. 8a,b.
1933	Marssonella "	(Reuss); Cushman, p. 36, Pl. 4, fig. 13a,
1937	" "	(Reuss); Loetterle, p. 59, Pl. 10, fig. 7.
1937	" "	(Reuss); Cushman, pp. 56-9, Pl. 5, figs, 27, 29. (non fig. 28). Pl. 6, figs, 3-5, 8-12. 6-7).
1946	" "	(Reuss); Keller, p. 92, Pl. 1, fig. 13,
1946	" "	(Reuss); Schijfsma, p. 38, Pl. 1, fig. 12a,b.
1946	" "	(Reuss); Cushman, p. 43, Pl. 12, figs. 3-5.
1952	" "	(Reuss); de Civrieu, p. 257, Pl. 2, figs. 15-16.
1953	" trochus	(d'Orbigny) in part; Barnard, in Barnard & Banner, p. 204, t. figs. 5 o-s.
1953	" oxycona	(Reuss); Hagn, p. 23, Pl. 1, fig. 28.

1957 " " (Reuss); Hofker, p. 85, t. figs. 86-90.

1957 " " (Reuss); McGugan, p.p. 337-8, Pl. 33, fig. 8

1963 " trochus (d'Orbigny); Barnard, p. 44, t. figs. 3a-q.

1964 Dorothia oxycona (Reuss); Loeblich & Tappan, p. C275, t. fig. 184, 5a-c.

1968 " " (Reuss); Sliter, p. 50. Pl. 3, fig. 13.

Test conical, tapering rapidly to an acute apical angle, first whorl has four chambers, all succeeding whorls are biserial, transverse section is initially round becoming more ovoid in the later stages; chambers fairly distinct, interiors simple with no signs of any internal partitions, usually not inflated; sutures fairly distinct, flush with surface of test or slightly depressed; wall thick, finely arenaceous with much calcareous cement; aperture a slightly arched broad slit along the margin of the final chamber.

Max. dimensions: Height 0.79mm. Width 0.65 mm.

Remarks: The genus Marssonella was originally placed within the synonomy of Dorothia, by Trujillo (1960) and subsequently by Loeblich & Tappan (1964). However, this is not considered to be the case by Carter (in Carter & Hart in press (B)), as he reinstates Marssonella as a separate genus. The present author shares this view, as Marssonella lacks the trochoid chamber arrangement seen in Dorothia. Also, at a lower taxonomic level, the chambers of the former never exhibit the degree of inflation seen commonly in the latter.

There has been some confusion in the past concerning the separation of the three species M. oxycona (Reuss) M. turris (d'Orbigny) and M. trochus (d'Orbigny), and this is discussed at some length by Owen (1970). With reference to the original figures of all three species the simplest method of differentiation is by examening the lateral outline of the specimen:

M. trochus (d'Orbigny) 1840 - concave conical outline

M. turris (d'Orbigny) 1840 - straight sided conical outline

M. oxycona (Reuss) 1860 - straight to more convex outline

The majority of the specimens examined in the present study fell within the morphological range of M. oxycona (Reuss), although the tendency was noted in some individuals to become more concave in outline, indicating a possible overlap in specific characters.

Range: Assemblage Zones A-F.

Genus EGGERELLINA Marie 1941

Genotype Bulimina brevis d'Orbigny 1840

Eggerellina gibbosa var. globulosa Marie 1941

Pl. 2, figs. 3 & 4.

1941 Eggerellina gibbosa var. globulosa Marie, pp. 35-6, Pl. VII, fig. 73a-d.

1953 " " " " Marie; Barnard, in Barnard & Banner, p. 203, Pl. VIII, fig. 12

Only two whorls present, both of three chambers; initial whorl extremely small and diminutive, totally dominated by globular inflated second whorl, marked difference in chamber size between the last chamber of the first whorl and the first chamber of the second whorl; sutures distinct, slightly depressed; walls finely arenaceous with calcareous cement, smooth; aperture simple linear hole set perpendicular to the inner margin of the final chamber, surrounded by a slight apertural lip.

Max. dimensions: Height 0.53 mm. Width 0.58 mm.

Range: Assemblage Zones A-E.

<u>Eggerellina gibbosa</u> var. <u>conica</u> Marie 1941

Pl. 2, fig. 5.

1941 <u>Eggerellina gibbosa</u> var. <u>conica</u> Marie, p. 35, Pl. VII, fig. 71a-d.

1953 " " " " Marie; Barnard, in Barnard & Banner, p. 203, Pl. VIII, fig. 13

Trochoid test, conical in outline with three to four whorls; initial whorls increasing uniformly in size, final whorl showing much greater inflation occuping over half the total length of the test, only two chambers visible when the apertural face is viewed from above; sutures distinct and slightly depressed; finely arenaceous wall with a calcareous cement, smooth in appearance; aperture similar to that in <u>E. gibbosa</u> var. <u>globulosa</u>, simple 'key-hole' shape set at right angles to the inner margin of the final chamber.

Max. dimensions: Height 0.86mm. Width 0.71 mm.

Range: Assemblage Zones A-F.

Subfamily ATAXOPHRAGMIINAE Schwager 1877

Genus ATAXOPHRAGMIUM Reuss 1860

Genotype <u>Bulimina variabilis</u> d'Orbigny 1840

<u>Ataxophragmium variabile</u> (d'Orbigny) 1840

Pl. 2, figs. 6-7.

1840 <u>Bulimina variabilis</u> d'Orbigny, p. 40, Pl. IV, figs. 9-11.

1851 " <u>preslii</u> Reuss, p. 39, Pl. IV, fig. 10a,b.

1878 " <u>globularis</u> (Reuss); Marsson, p. 153.

1891 <u>Polyphragma variabile</u> (d'Orbigny); Beissel, p. 20, Pl. IV, figs. 46-53.

1928 <u>Bulimina variabilis</u> d'Orbigny; Franke, pp. 155-6, Pl. XIV, fig. 9a,b.

1937 Ataxophragmium variabile (d'Orbigny); Cushman, p. 175, Pl. 21, figs. 10-15.

1941 Ataxogyroidina variabilis (d'Orbigny); Marie, p. 56, Pl. IV, figs. 41-2, Pl. V, figs. 43-4, 47.

1941 " cylindrica Marie, p. 57, Pl. V, fig. 46a, b.

1941 " ovoidea Marie, p. 57, Pl. V, fig. 40a, b.

1941 " concava Marie, p. 58, Pl. V, fig. 45a, b.

1941 " gibbosa Marie, p. 58, Pl. V, fig. 49a, e.

1941 " globosa (Hagenow); Marie, p. 59, Pl. V, figs. 50-7.

1941 " crassa (d'Orbigny); Marie, p. 59, Pl. VI, figs. 59-60.

1946 " " (d'Orbigny); Schijfsma, p. 36, Pl. 1, fig. 10a-c.

1946 " dufouri Schijfsma, p. 37, Pl. 1, fig. 9a, b.

1953 " variabilis (d'Orbigny); Barnard, in Barnard & Banner, pp. 205-6, Pl. IX, fig. 6a, b. t. fig. 7.

1964 Ataxophragmium variabile (d'Orbigny); Loeblich & Tappan, pp. C283-4, fig. 191, 1, 2.

Test loosely coiled spiral enrolled with the final whorl, two to three whorls, initial one totally enclosed within later chambers; chambers increase rapidly in size, reniform, interiors simple lacking internal partitions; sutures flush with surface of slightly depressed; wall fine to coarse arenaceous with much calcareous cement, surface smooth to rugose; apertural face flat; aperture usually simple semi-circular hole on the inner margin of the final chamber although the shape is very variable.

Max. dimensions: Height 0.95 mm. Width 0.68 mm. Breadth 0.76 mm.

Remarks: The genus _Ataxophragmium_, of which the present species is the genotype, has been a source of taxonomic confusion ever since d'Orbigny (1840) described the species as being extremely variable in form. Marie (1941) erected the genus _Ataxogyroidina_ into which he placed a range of tightly coiled species. However, he designated _Bulimina variabilis_ d'Orbigny as the type species, thus making the new genus a junior isogenotypic synonym of _Ataxophragmium_ (Loeblich & Tappan 1964).

The use of the name _Ataxogyroidina_ by Barnard (in Barnard & Banner 1953) for those species with simple interiors is also incorrect as this is not the case in the type specimens (Loeblich & Tappan). He, like the present author, found that specimens of _A. variabile_ from the Senonian of southern England consistantly have simple interiors, though this is obviously not the case elsewhere. Owen (1970) concluded "that both _Ataxophragmium_ and _Arenobulimina_ may have simple or complex interiors and that the presence or absence of internal structure is of specific value only". This is a broad statement to make in a discussion of the Lituolacea, although it may have some relevance in the present case.

The species _A. variabile_ (d'Orbigny) appears to be fairly long ranging through the Upper Cretaceous, and it is probably a continuation of the generic lineage started in the Cenomanian by _A. depressa_ (Perner). Franke (1925) recorded _Bulimina jackeli_ Franke as being the Turonian continuation of this lineage, but later (1928) includes this species within the synonomy of _A. depressa_. This species differs from _A. variabile_ in having a distinct depression centered on the aperture, whereas, as stated in the description, _A. variabile_ has a flat apertural face.

Range: Assemblage Zones A-F.

Suborder ROTALIINA Delage & Herouard 1896

Superfamily NODOSARIACEA Ehrenberg 1838

Family NODOSARIIDAE Ehrenberg 1838

Subfamily NODOSARIINAE Ehrenberg 1838

Genus NODOSARIA Lamark 1812

Genotype Nautilus radicula Linne 1758

Nodosaria aspera Reuss 1845

Pl. 2, fig. 8.

1846	Nodosaria (Nodosaria) aspera	Reuss, p. 26, Pl. XIII, figs. 14, 15.
1928	" aspera	Reuss; Franke, p. 50, Pl. IV, fig. 14.
1941	" "	Reuss; Marie, p. 87, Pl. XI, fig. 125.
1946	" "	Reuss; Cushman, p. 72, Pl. 26, fig. 6.
1953	" "	Reuss; Hagn, p. 49, Pl. 4, fig. 28.
1957	" "	Reuss; Pozaryska, p. 65, Pl. 7, fig. 3.
1963	" "	Reuss; Graham & Church, p. 41, Pl. 4, figs. 17, 18.
1968	" "	Reuss; Sliter, pp. 52-3, Pl. 4, fig. 11.

Test free, uniserial, rectilinear, tapering towards the base; chambers sub-globular, inflated increasing uniformly in size, circular in transverse section; sutures distinct, depressed, straight; chamber walls finely perforate calcite, walls around sutures and apertural neck more coarsely perforate, distinctly spinose; aperture terminal, situated at the end of a slender neck.

Max. dimensions: Length 0.62 mm. Width 0.27 mm.

Remarks: Reuss' type figures of this species are, as is often the case, poor and imprecise. However Reuss (1846, fig. 14) shows the spinose nature of the wall quite clearly, as well as having a distinct apertural neck, which is believed to be of particular importance.

Range: Assemblage Zones D-E.

Nodosaria gracilitatis Cushman 1938.

Pl. 2, fig. 9.

1938	Nodosaria gracilitatis	Cushman, p. 41, Pl. 6, figs. 23-26.
1940	" "	Cushman; Cushman, p. 89, Pl. 16. figs. 3-6.

Test rectilinear, uniserial, elongate, slender showing no increase in diameter throughout length; chambers long, cylindrical not inflated; sutures distinct, flush with surface to slightly depressed; walls, thin, perforate calcareous, distinct costae running the length of the test and fusing at the base of the proloculus; aperture terminal, radiate.

Max. dimensions: Length 0.71 mm. Width 0.21 mm.

Remarks: Specimens of this group examined during the course of this study, show a very close similarity to those recorded as paratypes by Cushman (1940, figs. 5, 6). However, his types are taken from the lower Taylor marl of Texas, which is in fact Campanian. The present species is therefore believed to be an early form.

Range: Assemblage Zone D.

Nodosaria naumanni Reuss 1874

Pl. 2, fig. 10.

1874	Nodosaria naumanni	Reuss, p. 82, Pl. II (20), fig. 11.
1925	" "	Reuss; Franke, p. 40. Pl. III, fig. 31.
1928	" "	Reuss; Franke, p. 42, Pl. III, fig. 29.
1940	" "	Reuss; Cushman, p. 89, Pl. 16, fig. 7.
1946	" "	Reuss; Cushman, p. 72, Pl. 26, fig. 11.

Test free, rectilinear, uniserial, tapering slightly towards the base; chambers distinct, slightly overlapping, becoming inflated, final chamber tends to be ovoid; sutures depressed, very distinct; wall smooth, quite thick calcite; aperture terminal, radiate.

Max. dimensions: Length 0.88 mm. Width 0.29 mm.

Range: Assemblage Zones C-F.

Nodosaria zippei Reuss 1845

Pl. 2, fig. II.

1845	Nodosaria zippei	Reuss, p. 25, Pl. VIII, figs. 1-3.
1893	" (Dentalina) zippei	Reuss; Chapman, p. 593, Pl. 9, fig. 12.
1932	" zippei	Reuss; Sandidge, pp. 275-8, Pl. 42, figs. 13, 14.
1950	" "	Reuss; Ten Dam, p. 27.
1957	" affinis	Reuss; McGugan, Pl. 31, figs. 20, 21.

Test large, uniserial, rectilinear, circular in transverse section; chambers inflated, globular; sutures flush to slightly depressed, distinct, horizontal; wall smooth, with large distinct costae running the full length of the test; aperture terminal, radiate, centrally positioned.

Max. dimensions: Length 6.83 mm. Width 1.46 mm. Measured on a broken specimen.

Remarks: It is believed that confusion exists between this species and N. affinis Reuss, which is also commonly recorded from the Upper Cretaceous. Reuss' type figures are quite distinctive in that N. affinis has ovoid chambers and an apterture which is situated at the end of a short neck. N. zippei however is therefore believed to extend higher than the Albian to Cenomanian distribution normally attributed to it.

Range: Assemblage Zones A-F.

Nodosaria sp. A.

Pl. 2, fig. 12.

1940 Dentalina megalopolitana Cushman (non Reuss), p. 80-81, Pl. 13, fig. 28 (non figs. 26-27).

Test large, mutlilocular, rectilinear, uniserial, circular to slightly ellipsoid in cross-section; chambers indistinct, uninflated; sutures flush with surface, horizontal; wall smooth, quite thick; aperture radiate, centrally positioned final chamber may be produced slightly.

Max. dimensions: Length 1.31 mm. Width 0.41 mm.

Remarks: The specimen of D. megalopolitana illustrated by Cushman (1940, Pl. 13, fig. 28), has a terminally positioned aperture, identical to that of the present species. His other two illustrations of this species, both have apertures positioned on the inner angle of the final chamber, in specimens with arcuate chamber arrangements. These are therefore considered to be D. megalopolitana Reuss.

Range: Assemblage Zones A-E.

Nodosaria sp. B.

Pl. 2, fig. 13.

Test uniserial, rectilinear, round in transverse section; chambers slightly inflated; sutures indistinct, flush to slightly depressed; wall calcareous, smooth, costate, with ribs running parallel for the length of the test, becoming oblique across the final suture; aperture radiate, at the end of a short neck.

Max. dimensions: Length 0.72 mm. Width 0.26 mm. Measured on a broken specimen.

Remarks: This species is similar to N. zippei Reuss, but its smaller size and characteristic twisting nature of the costae is very distinctive.

Range: Assemblage Zone C.

Nodosaria sp. C.

Pl. 2, fig 14.

Test unilocular, consisting of a large ovoid chamber, which may be sub-globular to more elongate; wall perforate, calcareous, smooth; aperture terminal, surrounded by a circular collar, possibly the base of a second chamber which was never secreted.

Max. dimensions: Length 0.46 mm. Width 0.30 mm.

Remarks: This species is extremely simple morphologically, giving the appearance of a large megalospheric proloculus. Numerous specimens have been found and it is therefore considered as a separate group. The species Nodosaria cidarina (Grzybowski) which was originally figured from the Lower Oligocene of Poland, and subsequently noted by Loeblich and Tappan (1964, p.C512, fig. 400), is almost identical with the present form, even to the presence of the apertural collar.

Range: Assemblage Zones B-F.

Genus CITHARINA d'Orbigny 1839

Genotype Vaginulina (Citharina) strigillata Reuss

Citharina cf. strigillata (Reuss) 1846

Pl. 2, fig. 15.

1846	Vaginulina (Citharina) strigillata	Reuss, p. 106, Pl. XXIV, fig. 29.
1899	" strigillata	Reuss; Egger, p. 101, Pl. X, figs. 7, 9, 12.
1928	" "	Reuss; Franke, p. 81, Pl. VII, fig. 21.
1936	" eriksdalensis	Brotzen, pp. 94-5, Pl. VI, fig. 3a, b.
1964	Citharina strigillata	Reuss; Loeblich & Tappan, pp. C514-6, Fig. 402. 10.

Test flattened, long, slender and roughly triangular in outline; chamber arrangement uniserial, slightly arcuate; chambers narrow, oblique, sutures distinct, oblique; wall calcareous, smooth, with vertical costae which may mask the sutures; aperture radiate, situated in a terminal position on the outer edge of the test.

Max. dimensions: Height 0.55 mm. Width 0.09 mm. measured on a damaged test.

Remarks: Reuss' original figure is by no means ideal although it does reveal all the necessary characteristics of the species. The erection of a new species by Brotzen (1936) is considered to be unnecessary as the specimens he figures are believed to be synonymous with C. strigillata (Reuss). However it should be noted that Sliter (1968) includes V. eriksdalensis Brotzen in his synonymy of C. multicostata (Cushman), a form described from the Gulf Coast of the U.S.A.

Range: Assemblage Zones B-F.

Genus CITHARINELLA Mârie 1938

Genotype Flabellina Karreri Berthelin 1880

Citharinella sp. A.

Pl. 2, fig. 16.

Test free, slightly compressed, flabelliform, margins sub-angular to rounded; chambers slightly arcuate initially, rapidly becoming uniserial, low equitant arrangement strongly arched, slightly inflated in the later stages; sutures distinct, slightly depressed, curved strongly downwards; wall finely perforate calcite, smooth; aperture terminal, radiate.

Max. dimensions: Length 0.71 mm. Width 0.49 mm.

Remarks: This is rare species which was only encountered in the Quidhampton section. The distinctive arrangement of the initial few chambers is similar to that of Citharina, as noted by Loeblich & Tappan (1964) in their discussion of the genus.

Range: Assemblage Zone D.

Genus DENTALINA Risso 1826

Genotype Nodosaria (Dentaline) cuvieri d'Orbigny 1826

Dentalina catenula Reuss 1860

Pl. 3, figs. 1& 2.

1860 Dentalina catenula Reuss, p. 185, Pl. III, fig. 6.

1899 Nodosaria " (Reuss); Egger, p. 61, Pl. VI, fig. 24.

1928 Dentalina " Reuss; Franke, p. 26, Pl. II, fig. 16.

1934 " " Reuss; Brotzen, p. 35.

1940 " " Reuss; Cushman, p. 81, Pl. 13, figs. 29-34.

1968 " " Reuss; Sliter, p. 57, Pl. 5, fig. 14.

Test rectilinear to slightly curved, initial end marked by the presence of a short spine; chambers pyriform, distinctly overlapping giving a slightly sub-globular appearance to earlier chambers; sutures depressed, horizontal, wide; wall smooth; aperture radiate, terminal, slightly off-centre.

Max. dimensions: Length 0.89 mm. Width 0.28 mm.

Remarks: Dentalina catenula Reuss bears strong similarities to D. distincta Reuss, although the latter tends to have much more ovoid chambers. Cushman (1940) notes that from a study of topotypic material, Dentalina oligostegia described in 1851 from the Cretaceous of Lemburg, again by Reuss, is the same as D. catenula. This would seem to suggest that, following the law of priority, D. catenula Reuss should possibly be placed in the synonymy of D. oligostegia Reuss, but without more detailed examination of type material the situation remains in some doubt.

The specimen figured (Pl. 3 fig. 1) is the megalospheric form, very similar to that illustrated by Cushman in 1940 (Pl. 13, fig. 32).
Range: Assemblage Zones B-E.

Dentalina megalopolitana Reuss 1855

Pl. 3, fig. 3.

1855	Dentalina megalopolitana	Reuss, p. 267, Pl. 8, fig. 10.
1925	Nodosaria "	(Reuss); Franke, p. 83, Pl. 3, fig. 8.
1931	Dentalina "	Reuss; Cushman, p. 29, Pl. 3, fig. 8.
1932	" "	Reuss; Cushman & Jarvis, p. 29 Pl. 9, fig. 5.
1940	" "	Reuss; Cushman, p. 80, Pl. 13, figs. 26, 27 (non fig. 28).
1944	" "	Reuss; Cushman & Deaderick, p. 332, Pl. 51, fig. 8.
1944	" "	Reuss, Cushman & Goudkoff p. 56 Pl. 9, fig. 11.
1946	" "	Reuss; Cushman, p. 67 Pl. 23, figs. 24-26.
1954	" "	Reuss; Frizzell, p. 89, Pl. 9, figs. 60, 61.
1957	" "	Reuss; Pozaryska, p. 84, Pl. 7, figs. 12, 13, t. fig. 17.

Test large, robust, slightly fusiform, beginning to taper at both ends, greatest width approximately mid-way along the test, ellipsoid in transverse section; chambers numerous, uninflated, indistinct; sutures horizontal to slightly oblique, flush with surface, final suture may become depressed; wall calcareous, thick and smooth; aperture radiate, produced slightly at the inner angle of the final chamber.
Max. dimensions: Length 3.89 mm. Width 0.56 mm.

Remarks: Cushman (1940) describes, and illustrates, this particular species extremely well, although one of his figures (Pl. 13 fig. 28) is believed to be Nodosaria sp. A in the present study, due to the central position of the aperture. It is also of note that the maximum length recorded in forms from the U.S.A. is 2.00 mm., whereas much larger examples may be found in the English succession.

Range: Assemblage Zones A-F.

Dentalina cf. monile (v. Hagenow) 1842

Pl. 3, fig. 4.

1842	Nodosaria monile	v. Hagenow, p. 568.
1846	" "	v. Hagenow; Reuss, p. 27, Pl. VIII, fig. 7.
1891	Dentalina "	(v. Hagenow); Beissel, p. 31, Pl. VI, figs. 30, 32-40.
1925	" "	(v. Hagenow); Franke, p. 34, Pl. III, fig. 11.
1928	" "	(v. Hagenow); Franke, p. 31, Pl. II, fig. 27.
1937	" "	(v. Hagenow); Marie, p. 264.
1941	" "	(v. Hagenow); Marie, p. 89, Pl. XI, figs. 127-130.

Test small, rectilinear uniserial, tapering towards the initial end, circular in cross-section; chambers distinct, inflated, slightly overlapping, increasing uniformly in size; sutures distinct, depressed, horizontal to slightly oblique; wall smooth, finely perforate; aperture radiate, terminal to slightly off centre.

Max. dimensions: Length 0.36 mm. Width 0.22 mm. Measured on an incomplete specimen.

Remarks: The representatives of this species found in the present study compare very closely with that illustrated by Franke (1928, Pl. II, fig. 27.) from the Upper Cretaceous of northern Germany.

The placing of the species within the genus Dentalina has been considered, as specimens are generally symmetrical with a centrally placed aperture, features associated with Nodosaria, which would verify vonHagenows' original classification.

Range: Assemblage Zones D-F

Dentalina nana Reuss 1862

Pl. 3, fig. 5.

1862	Dentalina nana	Reuss, p. 39, Pl. II, figs. 10, 18.
1899	" "	Reuss; Egger, p. 64, Pl. VII, figs. 18, 21.
1925	" "	Reuss; Franke, p. 35, Pl. III, fig. 19.
1928	" "	Reuss; Franke, p. 35, Pl. 3, fig. 2.
1929	" "	Reuss; Storm, p. 57.
1934	" "	Reuss; Brotzen, p. 34.
1936	" "	Reuss; Brotzen, p. 74, Pl. V, fig. 8.

Test uniserial, slightly arcuate, fusiform; chambers distinct, oblique, slightly inflated, more so in later stages; sutures flush with surface to very slightly depressed, distinct, oblique; wall calcareous, smooth; aperture radiate, terminally positioned on the inner margin of the final chamber.

Max. dimensions: Length 0.89 mm. Width 0.24 mm.

Remarks: Specimens examined in this study correspond very closely with that illustrated by Brotzen (1936), and the larger size noted in the present examples is not significant.

Range: Assemblage Zones C-F.

Dentalina pseudofiliformis Brotzen 1936

Pl. 3. fig. 6.

1860	Dentalina filiformis	Reuss, p. 188, Pl. III, figs. 8, 9.
1936	" pseudofiliformis	Brotzen, pp. 77-8, Pl. V, figs. 3-5.

Test elongate, slender, rectilinear to slightly curved, multilocular; chambers narrow, almost tubular with very slight inflation, initial stages shorter, more globular, becoming elongate as chambers are added; sutures distinct, sub-horizontal, slightly depressed; wall thin, smooth, calcareous; aperture radiate, terminal.

Max. dimensions: Length 1.41 mm. Width 0.23 mm.

Remarks: Reuss' type, figure of D. filiformis corresponds very closely to Brotzens (1936 Pl. V, fig. 4), and therefore fits within the range of variation which Brotzen illustrates for his new species. This whole range has been encountered in the lower Senonian of southern England and Brotzens wider interpretation is prefered.

Range: Assemblage Zones C-F.

Dentalina cf. wimani Brotzen 1936

Pl. 3, fig. 7.

1936 Dentalina wimani Brotzen, pp. 76-7, Pl. V, figs. 16, 17.

Test, uniserial, rectilinear to slightly arcuate, proloculus marked at base by a short spine; chambers distinct, slightly oblique, gradually increasing in size, slender at base; sutures distinct, sub-horizontal, slightly depressed; wall smooth, thin; aperture radiate, terminally positioned on the innermost edge of the final chamber.

Max. dimensions: Length 0.81 mm. Width 0.18 mm.

Remarks: Specimens correspond well with Brotzens' (1936, Pl. V, fig. 16), although the chambers are slightly larger in the present example, thus the trivial name is used simply for comparison.

Range: Assemblage Zone F.

Genus FRONDICULARIA Defrance in d'Orbigny 1826

Genotype Frondicularia inversa Reuss 1860

Frondicularia angulosa d'Orbigny 1839

Pl. 3, fig. 8.

1839 Frondicularia angulosa d'Orbigny, p. 22, Pl. I, fig. 39.

1845 " " d'Orbigny; Reuss, p. 31, Pl. XIII, fig. 40 Pl. VIII, fig. 78.

1846 " " d'Orbigny; Reuss, p. 107, Pl. XXIV, fig. 42.

1910 " " d'Orbigny; Heron-Allen & Earland, p. 418, Pl. 7, fig. 10.

1928 " " d'Orbigny; Franke, p. 71, Pl. VI, fig. 13a, b.

1936 Frondicularia cf. angulosa d'Orbigny; Brotzen, pp. 104-5, Pl. VI, figs. 15, 16, 18, t. fig. 32.

1941 " pedicellaris Marie, p 126, Pl. XV, fig. 181.

Test consisting of a globular proloculus, with a small number of chambers tending towards the formation of an elongate form, edge of test squared, produced into two slight rims; chambers broad equitant, two vertical ribs present on the proloculus; sutures raised as low, broad ribs; wall smooth; aperture terminal, radiate.

Max. dimensions: Length 0.92 mm. Width 0.35 mm.

Remarks: The original figure illustrated by d'Orbigny in 1840 is probably that of a juvenile test, and gerontic stages may well have been referred to as separate species. This is difficult to determine, although large specimens have been recorded with only two chambers built on to the proloculus.

Range: Assemblage Zones A-F.

Frondicularia archiaciana d'Orbigny 1840

Pl. 3. fig. 9.

1840	Frondicularia archiaciana	d'Orbigny, p. 20. Pl. I, figs. 34-6.
1845	" "	d'Orbigny; Reuss, p. 31, Pl. XIII, fig. 29.
1891	" "	d'Orbigny; Beissel, p. 39, Pl. VIII, figs. 1-12.
1899	" "	d'Orbigny; Egger, p. 87, Pl. X, figs. 19, 20.
1925	" "	d'Orbigny; Franke, p. 52, Pl. II, fig. 18.
1928	" "	d'Orbigny; Franke, p. 71, Pl. VI, figs. 14, 15a, b.
1946	" "	d'Orbigny; Cushman, p. 91 Pl. 37, figs. 8-20.
1954	Pseudofrondicularia archiaciana	(d'Orbigny); Frizzell, p. 99, Pl. 13, figs. 6-8.
1957	Frondicularia archiaciana	d'Orbigny; Pozaryska, p. 137, Pl. 21, fig. 3.
1963	" "	d'Orbigny; Graham & Church, p. 31, Pl. 2, figs. 21-2.
1968	" "	d'Orbigny; Sliter, pp. 59-60, Pl. 6, fig. 2.

Test elongate, tapering gradually towards the base, compressed, marginal edges truncate; chambers low, equitant, increasing gradually in size; sutures distinct, slightly raised, becoming sigmoidal; wall smooth, proloculus bears three or more vertical costae; aperture radiate, terminal, slightly produced, with a short neck.

Max. dimensions: Length 0.58 mm. Width 0.25 mm. Measured on a juvenile specimen, as complete adults have not been found.

Remarks: Sliter (1968) notes that Frondicularia archiaciana, as illustrated by Belford (1960), should not be included in d'Orbignys' species due to the presence of fine longitudinal costae, which appear to be more typical of F. intermittens Reuss. This feature is also noted in F. archiaciana as figured by Hart (1970).

Range: Assemblage Zone D.

Frondicularia goldfussi Reuss 1860

Pl. 3, fig. 10.

1860	Frondicularia goldfussi	Reuss, p. 192, Pl. IV, fig. 7a,b.
1946	" "	Reuss; Cushman, p. 87, Pl. 34, figs. 18-20, Pl. 35, figs. 1, 2.
1951	" "	Reuss; Bandy, p. 497, Pl. 72, fig. 6.
1957	" "	Reuss; Pozaryska, p. 143, Pl. 22, fig. 4, Pl. 25, fig. 3.
1968	" "	Reuss; Sliter, p. 61, Pl. 6, fig. 4.

Test broad, extremely compressed, maximum width developed after $\frac{1}{4}$ of the length of the test, chambers very elongate, low in early stages with a slight inflation later; sutures flush, equitant, slightly limbate, proloculus extremely elongate, produced to a short basal spine; wall smooth, finely perforate; aperture terminal, radiate.

Max. dimensions: Length 0.63 mm. Width 0.31 mm.

Remarks: Reuss' (1860) original figure of F. goldfussi, despite its stylised appearance, is believed to be the microspheric generation of the species. Differences between this figure and the specimens examined are due to the majority of the latter being megalospheric forms.

Range: Assemblage Zones C-E.

Frondicularia inversa Reuss 1844

Pl. 3, fig. 11.

1844	Frondicularia inversa	Reuss, p. 211.
1845	" "	Reuss; Reuss, p. 31, Pl. VIII, figs. 15-19, Pl. XIII. fig. 42.
1892	" "	Reuss; Perner, p. 59. Pl. 7, fig. 9.
1936	" "	Reuss; Brotzen, p. 96, Pl. 6, fig. 12.
1936	" "	Reuss; Cushman, p. 16, Pl. 3, figs. 23,24.
1946	" "	Reuss; Cushman, p. 86, Pl. 33, figs. 11-18.
1953	" "	Reuss; Hagn, pp. 63-4, t. fig. 8.
1954	" "	Reuss; Frizzell, p. 98, Pl. 12, figs. 31, 32.
1957	" "	Reuss; Pozaryska, p. 145, Pl. 23, fig. 8, t. plate 3, fig. 1.
1966	" "	Reuss; Butt, p. 172, Pl. 1. fig. 6.
1968	" "	Reuss; Sliter, p. 62, Pl. 6, fig. 6.

Test palmate, elongate, very compressed, margins sharply rounded, maximum width mid-way along test; chambers low, elongate, later ones failing to reach the level of the proloculus, proloculus long, narrow; sutures flush with surface, equitant, straight to slightly curved; wall calcareous, smooth; aperture terminal, radiate.

Max. dimensions; Length 1.23 mm. Width 0.46 mm.

Remarks: F. inversa and F. goldfussi do bear some resemblance to each other, however the failure of the later chambers to reach beyond mid-way down the test is fairly characteristic of the former.

Range: Assemblage Zones C-D.

Frondicularia schenkei Brotzen 1936

Pl. 3, fig. 12.

1932 Frondicularia goldfussi Reuss; Cushman, p. 336, Pl. 50, figs. 8, 9.

1936 " schenkei Brotzen, p. 100, Pl. VI, fig. 11.

Test broadly palmate, margins truncated, expanding rapidly from the proloculus; chambers flat, elongate, broad equitant, slightly convex, proloculus globular, ornamented by three or more radiating costae; sutures becoming limbate; wall smooth, fairly robust, aperture terminal, radiate.

Max. dimensions: Length 1.08 mm. Width 0.83 mm.

Remarks: A rare form in southern England which is also poorly recorded in other European sections.

Range: Assemblage Zone C.

Frondicularia striatula Reuss 1844

Pl. 3, fig. 15.

1844 Frondicularia striatula Reuss, p. 212.

1845 " " Reuss; Reuss, pp. 30-31, Pl. VIII, fig. 23.

1846 " " Reuss; Reuss, p. 107, Pl. XLIII, fig. 11.

1925 " " Reuss; Franke, pp. 51-2, Pl. 4, fig. 15.

1928 " " Reuss; Franke, pp. 67-8, Pl. 6, figs. 1a, b, 2.

1936 " " Reuss; Cushman, p. 18, Pl. 4, figs. 4, 5.

1946 " " Reuss; Cushman, pp. 90-1, Pl. 37, figs. 1-4.

1957 " " Reuss; Hofker, p. 109, t. fig. 109c-d, p. 152, t. fig. 183a-f.

1957 " " Reuss; McGugan, p. 333, Pl. 31, fig. 12.

Test large, robust, elongate, margins distinctly truncated, chambers low, not expanded, equitant, straight, sutures raised, distinctly limbate, straight; wall robust, longitudinal striations running the length of the test; aperture terminal, radiate.

Max. dimensions: Length 1.32 mm. Width 0.54 mm. Measured on an incomplete specimen, broken at both ends.

Remarks: The distinctly truncated edges of this species, with the longitudinal striations, make it very distinctive, although it has only been noted in occasional samples from Norfolk and Essex.

Range: Assemblage Zone A – Assemblage Zone F.

<u>Frondicularia sp. A</u>

Pl. 3, fig. 13.

Test large, sides sub-parallel, gradually increasing in size from the base, margins rounded, distinctly ellipsoidal in transverse section; chambers indistinct, flat, chevron arrangement; sutures indistinct, flush with surface; wall robust, smooth, internally septa raised; aperture not seen in full specimen, appears to be terminal and radiate in younger chambers.

Max. dimensions: Length 1.18 mm. Width 0.65 mm. Measured on an incomplete specimen.

Remarks: This species, easily identified by its smooth external appearance and distinctive cross-section, has been noted at levels throughout the present study, and also in older material from the Turonian.

Range: Assemblage Zones A-F.

Frondicularia sp. C.

Pl. 3, fig. 14.

Test extremely large, wedge-shaped increasing uniformly in size, margins sharply truncated; chambers equitant, uninflated; sutures slightly limbate, chevron type arrangement; wall robust, calcareous, smooth; aperture rarely seen in complete specimens, appears to be centrally terminal, radiate.

Max. dimensions; Length 4.02 mm. Width 0.81 mm. Measured on an incomplete specimen, broken at both ends.

Remarks: Species is extremely close to Frondicularia striatula Reuss, in gross morphology and size, however the lack of a longitudinal striate ornament makes the present form distinct.

Range: Assemblage Zones A-F.

Genus LAGENA Walker & Jacob in Kanmacher 1798

Genotype Serpula (Lagena) sulcata Walker & Jacob 1798

Lagena ellipsoidalis Schwager 1878

1878	Lagena ellipsoidalis	Schwager, p.512, Pl.1, fig.1.
1899	" "	Schwager; Egger, p.102, Pl.5, fig.1.
1936	" "	Schwager; Brotzen, p.110, Pl.VII, fig.4, t.fig.36.

Test free, ellipsoidal, globular, unilocular; chamber ovoid, with small central spine at the base; wall calcareous, smooth to irregular; aperture simple, at the end of a centrally positioned, short, smooth apertural tube.

Max. dimensions: Length 0.37 mm. Width 0.28 mm.

Range: Assemblage Zones A-F.

<u>Lagena hispida</u> Reuss 1863

Pl. 4, fig. 2.

1863	<u>Lagena hispida</u>	Reuss, p. 335, Pl. VI, figs. 77-9.
1925	" "	Reuss; Franke, p. 60, Pl. 5, fig. 5.
1928	" "	Reuss; Franke, p. 88, Pl. 8, fig. 6.
1931	" "	Reuss; Cushman, p. 37, Pl. 5, fig. 6.
1941	" "	Reuss <u>forma typica</u> Franke; Marie, p. 76, Pl. 9, fig. 89.
1941	" "	Reuss var. <u>subspaerica</u> Marie, p. 77. Pl. 9, fig. 90.
1941	" "	Reuss var. <u>ovoidea</u> Marie, p. 77, Pl. 9, fig. 91.
1946	" "	Reuss; Cushman, p. 93, Pl. 39, fig. 13.
1949	" "	Reuss; Cushman, p. 6, Pl. 3, fig. 8.
1953	" "	Reuss; Hagn, p. 68, Pl. 2, fig. 31.
1957	" "	Reuss; Pozaryska, p. 47, Pl. 2, fig. 8, (non Pl. 3, fig. 3.).
1968	" "	Reuss; Sliter, p. 64, Pl. 6, fig. 21.

Test free, small, globular to slightly ovoid, with a short apertural neck; unilocular; wall calcareous, finely perforate, distinct spinose ornament covering whole test; aperture terminal, simple.

Max. dimensions: Length 0.34 mm. Width 0.32 mm.

Remarks: An uncommon species in the present study, although widely discussed elsewhere, Sliter notes that in the past some authors have placed incomplete specimens of other species into this group; this includes <u>Lagena hispida</u> Reuss of Pozaryska (1957, Pl. 3, fig. 3.).

Range: Assemblage Zone D.

Lagena isabella d'Orbigny 1840

Pl. 4, fig. 3.

1840	Lagena isabella	d'Orbigny, p. 20, Pl. V, fig. 28.
1878	" "	d'Orbigny; Marsson, pp. 120-1.
1925	" "	d'Orbigny; Franke, p. 60, Pl. IV, fig. 40.
1928	" "	d'Orbigny; Franke, p. 87, Pl. VIII, fig. 1.
1936	" "	d'Orbigny; Brotzen, pp. 111-2, Pl. VII, fig. 5, t. fig. 37.

Test free, normally unilocular but may possess a second indistinct chamber, globular, ovoid, base rounded, may be produced into a short, central spine; wall calcareous, finely perforate with numerous longitudinal ribs, commencing below the neck and passing round to the base; aperture simple, round, situated at the end of a slender apertural tube.

Max. dimensions: Length 0.47 mm. Width 0.27mm.

Remarks: A species extremely similar to Lagena acuticosta Reuss, and when the variation in morphology illustrated by Brotzen (1936, t. fig. 37) is taken into consideration the species are probably conspecific, L. isabella having priority.

Range: Assemblage Zones A-F.

Genus LENTICULINA Lamark 1804

Genotype Lenticulina rotulata Lamark 1804

Lenticulina ovalis (Reuss) 1844

Pl. 4, fig. 4.

1844	Cristellaria ovalis	Reuss, p. 213.
1845	" "	Reuss; Reuss, pp. 34-5, Pl. VIII, fig. 49, Pl. XII, fig, 19, Pl. XIII, figs. 60-63. (type figs.)

1865	" "	Reuss; Eichwald, p. 184.
1866	" "	Reuss; Reuss, p. 141.
1872	" "	Reuss; Jones & Parker, p. 123.
1874	" "	Reuss; Reuss, pp. 103-4, Pl. II, figs. 6-11.
1882	" "	Reuss; Jones, p. 15 (Synonomy only).
1925	" "	Reuss; Franke, pp.67,72. Pl. VI, figs. 3a,b.
1928	" "	Reuss; Franke, pp. 96,107-8, Pl. X, fig. 1a,b.
1935	Robulus cf. ovalis	(Reuss); Eichenberg, p. 155, Pl. 16, fig. 6.
1953	Lenticulina "	(Reuss); Hagn, p. 36, Pl. 3, fig. 6.
1957	" "	(Reuss); Pozaryska, p. 126, Pl. 15, fig. 4.
1963	" "	(Reuss); Graham & Church, p. 35, Pl. 3, figs. 12,13.
1968	" "	(Reuss); Sliter, pp. 66-7, Pl. 7, fig. 12.

Test, sub-triangular, large globular initial chamber onto which smaller chambers are added planispirally; chambers indistinct, apart from large proloculus; sutures flush, slightly curved; wall finely perforate, smooth; aperture radiate, situated at peripheral apex of final chamber.

Max. dimensions: Length 0.68mm. Width 0.42mm.

Remarks: A common, long-ranging species in this country noted as Lenticulina gaultina (Berthelin) form ovalis by Hart (1970) from the Middle Albian to Lower Turonian, and as Lenticulina ovalis (Reuss) by Owen (1970) from throughout the Turonian.

Range: Assemblage Zones A-F.

Lenticulina rotulata s. l. (Lamark) 1804

Pl. 4, figs. 5, 6, 7. Pl. 15, fig. 1.

1804 Lenticulites rotulata Lamark, p. 185.

1806 " " Lamark; Larmark, Pl. 62, fig. 11

1840 Cristellaria " (Lamark); d'Orbigny, p. 26, Pl. II, figs. 15-18.

1845 " " (Lamark); Reuss, p. 34, Pl. VIII, figs. 50, 70. Pl. XII, fig. 25.

1846 " " (Lamark); Reuss, p. 109, Pl. XXIV, figs, 48,49.

1891 " " (Lamark); Beissel, p. 55, Pl. X, figs. 20-43.

1899 " " (Lamark); Egger, p. 122, Pl. XI, figs. 3, 4.

1925 " " (Lamark); Franke, p. 72, Pl. VI, fig. 4.

1928 " " (Lamark); Franke, p. 108, Pl. X, fig. 2.

1941 Lenticulina rotulata Lamark; Marie. 104-5, Pl. X, figs. 111-2.

1946 " " (Lamark); Cushman, p. 56, Pl. 18, fig, 19, Pl. 19, figs. 2-7. (non fig. 1.)

1957 " (Robulus) rotulata (Lamark); Hofker, p. 129, t. figs. 147-8.

1962 " rotulata (Lamark); Jefferies, Pl. 79, fig. 23.

1964 " " (Lamark); Loeblich & Tappan, pp. C519-520, t. fig. 406. 1.

1967 " (Lenticulina)rotulata (Lamark); Marks, p. 431, t. fig, 3,4.

Test free, large, lenticular biumbonate, may become asymmetrical rarely, margins sharply angled, often carinate, planispirally coiled; chambers subtriangular in section, expanding uniformly in size, distinct; sutures slightly curved, normally flush, may become slightly limbate; wall smooth, devoid of ornament, central umbilical boss may be developed; aperture radiate, on peripheral margin of final chamber, short apertural neck may be present.

Max. dimensions: Diameter 2.11 mm. Thickness 1.04 mm.

Remarks: An extremely common species which is also very variable in gross morphology. The actual definition of morphological variation is unclear, and the group can be considered as a broad range of minor variants. The more important variable characters are illustrated (Pl. 4:3), including the development of more nodose sutures and the presence of a central boss. The asymmetrical development of the group is also a problem in a taxonomic discussion at the species level.

Range: Assemblage Zones A-F.

Lenticulina sp. A cf. L. pseudonavicula (Marie)

Pl. 4, fig. 8.

1941 Saracenaria pseudonavicula Marie, pp. 110-1, Pl. X, figs. 113-4.

Test free, lenticuline, planispiral, distinctly asymmetric, margins sharply acute; chambers subtriangular, distinct; sutures straight to slightly curved, flush with surface; wall calcareous, smooth; aperture on peripheral margin of final chamber, radiate.

Max. dimensions: Diameter 0.62 mm. Thickness 0.29 mm.

Remarks: A species very similar to the L. rotulata group, showing a distinct asymmetric development in the later chambers, although not reaching the stage at which the test becomes uncoiled, a feature characteristic of the genus Saracenaria.

There exists considerable confusion with regards to the separation of the Lenticulina and Saracenaria lineages, a situation not helped by the erection of the species Astacolus jarvisi by Brotzen (1936), for a syntypic suite with a distinct range in shape between the two former genera.

D'Orbigny (1840) illustrates Cristellaria navicula with a distinctly lenticuline form, and C. triangularis which is becoming uncoiled. Maries' Saracenaria pseudonavicula is lenticuline, and simply a slight variant of C. navicula d'Orbigny. It is here placed back in the genus Lenticulina, on the basis of overall shape. Brotzen (1936) erected the species Astacolus jarvisi although he failed to define a holotype, as his description is based on a syntypic suite of morphological variants. Following the law of priority, his first figure (1936, Pl. 3, fig. 5.) is used as the holotype. This specimen has a broad apertural face and is totally planispiral, whereas the second specimen illustrated by Brotzen (Pl. 3, fig. 6.) is clearly uncoiled and rectilinear in its final stages. As such, it falls within the definition of Saracenaria. Brotzens' third example (Pl. 3, fig. 7.) is a lenticuline form, similar to C. navicula d'Orbigny.

Due to this confusion created by Brotzen, Saracenaria jarvisi (Brotzen) as defined by Sliter (1968) is incorrect. His figure (Pl. 8, fig. 22) shows a form which is becoming rectilinear in its later stages, and is stated in fact to be conspecific with figure 6. Brotzen. As already discussed, this is probably a Saracenaria, but cannot be S. jarvisi as the name is occupied by the specimen illustrated in figure 5. Sliter has also labelled his figures of S. jarvisi wrongly in the text, which does not help to clarify the problem.

Range: Assemblage Zones B - F.

Lenticulina sp. B.

Pl. 4, fig. 9.

Test free, asymmetrically planispiral, the final chambers becoming distinctly elongate, margins acute; chambers sub-triangular, increasing rapidly in size; sutures flush with surface, indistinct; wall calcareous, smooth; aperture radiate, terminal on apical point of final chamber.

Max. dimensions: Height 0.62 mm. Width 0.32 mm.

Remarks: An uncommon form showing an extremely asymmetric development of the final few chambers. However, there is no evidence of any uncoiling, and the species is left within the genus Lenticulina.

Range: Assemblage Zone C.

Genus MARGINULINA d'Orbigny 1826

Genotype Marginulina raphanus d'Orbigny 1826

Marginulina bullata Reuss 1845

Pl. 4, fig. 10.

1845	Marginulina bullata	Reuss, p. 29, Pl. XIII, figs. 34-8.
1860	" "	Reuss; Reuss, p. 61, Pl. VI, fig. 6.
1870	" "	Reuss; Karrer, p. 177.
1878	Cristellaria "	(Reuss); Marsson, p. 142.
1899	Marginulina "	Reuss; Egger, p. 95, Pl. IX, figs. 9, 10, 12, 13.
1925	" "	Reuss; Franke, p. 55, Pl. IV, fig. 25.
1928	" "	Reuss; Franke, p. 76, Pl. VI, fig. 28.
1929	" "	Reuss; Storm, p. 57.
1936	" "	Reuss; Brotzen, pp. 62-3, Pl. IV, fig. 1a-c, t. fig. 19.
1946	" "	Reuss; Cushman, p. 62, Pl. 21, figs. 32-37.
1951	" "	Reuss; Bandy, p. 498, Pl. 72, fig. 13.
1953	" "	Reuss; Hagn, p. 40 Pl. 4, fig. 1.
1957	" "	Reuss; Pozaryska, p. 106, Pl. 12, fig. 6.
1968	" "	Reuss; Sliter, p. 70, Pl. 8, fig. 7. (non fig. 6.)

Test free, slightly arcuate, initial chambers coiled, later stages becoming more uniserial, circular in transverse section; chambers initially small, rapidly inflating to become globular, later chambers remaining the same size; sutures slightly depressed; wall smooth, finely perforate; aperture radiate, often at the end of a short apertural tube, on the uppermost surface of the final chamber.

Max. dimensions: Length 0.54 mm. Width 0.34 mm.

Remarks: A very variable species, which seems to exhibit differences in the number of inflated sub-spherical chambers present in the rectilinear stage. Sliter (1968) suggests two distinct forms depending on this variation in the number of inflated chambers, although it is noted that he retains them as one species. This is a policy which is followed here.

Range: Assemblage Zones C-F.

Marginulina sp. cf. M. compressa (d'Orbigny) 1840

Pl. 4, fig. 11.

1840 Marginulina compressa d'Orbigny, p. 17, Pl. I, figs. 18,19.

Test free, elongate, arcuate, very compressed, ovoid in cross-section, margins rounded; chambers oblique, uniflated, fairly compressed; sutures flush with surface of test, oblique, slightly sigmoidal; wall smooth, finely perforate; aperture radiate, positioned terminally.

Max. dimensions: Length 1.21 mm. Width 0.39 mm.

Remarks: This species corresponds very closely to d'Orbignys' original description of M. compressa, although it shows some variation in width when compared with his stylised illustration.

A similar species was described by Brotzen (1936), and referred it to Planularia richteri. However, one of the characteristic features of the genus Planularia is a carinate margin, whereas P. richteri is rounded. It is believed therefore, that Brotzens' species may be conspecific with Marginulina sp. cf. M. compressa.

Range: Assemblage Zones A-D.

Marginulina sp. A

Pl. 4, fig. 12.

Test large, elongate, compressed, slightly arcuate; chambers indistinct, ovoid in section; sutures flush to very slightly limbate, sub-horizontal to oblique; wall robust, smooth, perforate, calcareous; aperture radiate, terminal on the outer periphery of the final chamber.

Max. dimensions: Length 2.02 mm. Width 0.50 mm.

Remarks: A large distinctive form, which although common, is of little stratigraphic value as it ranges throughout the Coniacian and lower Santonian of this country.

Range: Assemblage Zones A-F.

Marginulina sp. B.

Pl. 4, fig. 13.

Test large, broad, slightly arcuate with sharply rounded margins; chambers low, slightly oblique, strongly compressed; sutures flush to slightly depressed, sigmoidal, indistinct; wall thick, finely perforate, smooth; aperture terminal, situated on the uppermost point of the peripheral margin, radiate.

Max. dimensions: Length 1.43 mm. Width 0.73 mm.

Remarks: Similar to the form which Sliter (1968) records as Astacolus sp. (p. 55, Pl. 5, fig. 5), although the present species is believed to be coiled initially and is therefore included in the genus Marginulina.

Range: Assemblage Zones A-F.

Genus NEOFLABELLINA Bartenstein 1948

Genotype Flabellina rugosa d'Orbigny 1840

Neoflabellina baudouiniana (d'Orbigny) 1840

Pl. 4, fig. 14.

1840 Flabellina baudouiniana d'Orbigny, p. 24, Pl. II, figs. 8-11.

1845 " " d'Orbigny; Reuss, p. 32, Pl. VIII, fig. 36a,b.

1853 " " d'Orbigny; Bronn, p. 82, Pl. 29, fig. 20 a,b.

1910 " " d'Orbigny; Heron-Allen & Earland, Pl. 8, fig. 4.

1925 " " d'Orbigny; Franke, pp. 63, 65, Pl. 5, fig. 15.

1928 " " d'Orbigny; Franke, p. 94, Pl. 8, fig. 16.

1940 " " d'Orbigny; Wedekind, pp. 180-1, t. fig. 2a-c.

1953 Neoflabellina " (d'Orbigny); Pozaryska, pp. 262-3, t. fig. 10a, b.

1958 " " (d'Orbigny); Witwicka, Pl. 8, fig. 1.

1970 " " (d'Orbigny); Porthault, in Donze et al, p. 54, Pl. 8, fig. 6.

1970 Neoflabellina aff. baudouiniana (d'Orbigny); Porthault, in Donze et al. p. 54, Pl. 8, fig. 9.

Test free, often large, palmate with an initial planispiral enrolled section, becoming uncoiled in the later stages; chambers initially arc-shaped, flat sided, with truncated margins, later becoming more broadly equitant; sutures distinct as sharply raised ridges; wall perforate calcite, normally smooth, occasional development of small nodes on the sides, mid-way between the sutures; aperture terminal, at the end of a short apertural neck.

Max. dimensions: Length 2.16 mm. Width 1.60 mm.

Remarks: Owen (1970) recorded this species as being distributed throughout the Turonian of southern England, although the original description was from Campanian material. The suggested overall range is therefore much longer than that recorded in the present study.

Porthault (1970) records, as a separate group, those forms which are extremely ornamented and large, although these are thought to be simply gerontic stages living in a favorable environment.

Included within this group are specimens which lack the very distinctive ornament and septal ridges typical of the species. The sutures in these individuals are becoming limbate, but do not exhibit the sharp nature of the true N. baudouiniana as figured by d'Orbigny (1840). The wall is also much smoother, lacking the development of any form of sculpture.

Range: Assemblage Zones A-F.

Neoflabellina deltoidea (Wedekind) 1940

Pl. 4, fig. 15.

1940 Flabellina deltoidea Wedekind, pp. 186, 190, 194, figs. 3,4,6.

1940 " " mut. pachydisca Wedekind, p. 186-191, figs. 3a-c, 4a-c.

1956 Neoflabellina deltoidea (Wedekind); Hiltermann & Koch, p. 37 fig. 4. n° 1-6, Pl. 1,2, fig. 2.

1962 " " (Wedekind); Hiltermann & Koch, p. 308, Pl. 48, fig. 12.

1970 " " (Wedekind); Porthault, in Donze et al, pp. 54,5. Pl. 8, figs. 4,5.

Test free, broadly palmate, compressed, rhomboid in outline, initial planispiral coil weakly developed, totally enclosed by later chambers; chambers distinct, flat, initially sub-triangular later becoming broadly equitant; sutures distinct, slightly raised to form septal ridges; wall finely perforate, normally smooth, occasional development of small nodes on the side faces; aperture terminal, a short apertural neck is frequently developed, radiate.

Max. dimensions: Length 0.66 mm. Width 0.49 mm. Measured on an incomplete specimen.

Remarks: Wedekinds' species has not been further divided into sub-species in the present study as most of the material was not sufficiently well preserved. However, Porthault (1970) states that there are insufficient differences in Wedekinds sub-species to allow for their separation.

Range: Assemblage Zones C-F.

<u>Neoflabellina praerugosa</u> Hiltermann 1952

Pl. 4, fig. 16.

1952	<u>Neoflabellina praerugosa</u>	Hiltermann, p. 53, fig. 3, no. 12, 13.
1962	" "	Hiltermann; Hiltermann & Koch, pp. 307-8, Pl. 49, fig. 12.
1966	" "	Hiltermann; Salaj & Samuel, p. 133, Pl. 27, fig. 21.
1970	"	Hiltermann, Porthault, in Donze et al. pp. 52-3, Pl. 8, fig. 7.

Test free, initial portion planispirally coiled later becoming rectilinear, compressed, margins truncated with a slightly raised rim;

chambers initially sub-triangular later becoming equitant as the test becomes uncoiled, sutures distinct, marked by sharp raised ridges, separated in the centre by a remant apertural neck; wall finely perforate, small nodes rarely developed on some early chambers, normally smooth; aperture terminal, with the development of a short neck, finely radiate.

Max. dimensions: Length 0.67 mm. Width 0.50 mm. Measured on a specimen broken at the apertural end.

Remarks: This species is distinct from N. deltoidea (Wedekind) in that the initial planispiral section is not fully enclosed by the development of later chambers.

Its' distribution appears to be of some importance as it is first found early in the Coniacian, and is consistant throughout this stage, becoming rare in the lower Santonian and developing eventually into N. rugosa (d'Orbigny) early in the Campanian.

Range: Assemblage Zones A-F.

Genus PLANULARIA Defrance in De Blainville 1826.

Genotype Peneroplis auris Defrance in De Blainville 1826

Planularia liebusi Brotzen 1936

Pl. 5, fig. 1.

1936 Planularia liebusi Brotzen, pp. 60-1, Pl. IV, figs. 5a,b, 6a,b, t. fig. 18.

Test free, broadly arcuate, compressed, margins truncated, edges rounded; chambers flat, compressed, distinctly oblique, slightly curved; sutures oblique, slightly limbate, sigmoidal in early stages later becoming arc-like; wall smooth, rare indications of longitudinal ornament, realised as small gaps in the raised sutures; aperture radiate, terminal, on the peripheral margin of the final chamber.

Max. dimensions: Length 0.67 mm. Width 0.34 mm.

Remarks: Brotzen fails to distinguish a useful range for this species, although he suggests a distribution which terminates in the Turonian. This is not believed to be the case as numerous examples have been found throughout the interval under consideration.

Range: Assemblage Zones B-D.

Genus PSEUDONODOSARIA Boomgaart 1949

Genotype Glandulina discreta Reuss 1850

Pseudonodosaria obesa (Loeblich & Tappan) 1955

Pl. 5, fig. 2.

1955 Rectoglandulina obesa Loeblich & Tappan, p. 5, Pl. 1, figs. 5a-6.

1963 " " Loeblich & Tappan; Graham & Church, p. 46, Pl. 5, fig. 1.

1964 Pseudonodosaria " (Loeblich & Tappan); Loeblich & Tappan, pp. C522-4, fig. 408. 5, 6.

1968 " " (Loeblich & Tappan); Sliter, p. 72, Pl. 8, fig. 17.

Test free, uniserial, robust, the widest point falling slightly above the mid-point of the test, base pointed, widening out rapidly; chambers very strongly overlapping, becoming very globular in later stages; sutures horizontal, flush to very slightly depressed, distinct; wall perforate, smooth; aperture terminal, central, distinctly radiate.

Max. dimensions: Length 0.43 mm. Width 0.29 mm.

Remarks: First described from the Campanian Ozan sands of Arkansas U.S.A., the appearance of this species in the lower Santonian of this country is unusual, and also extremely rare.

Range: Assemblage Zone E.

Genus SARACENARIA Defrance in De Blainville 1824.

Genotype Saracenaria italica Defrance 1824.

Saracenaria triangularis (d'Orbigny) 1840

Pl. 5, fig. 3.

1840	Cristellaria triangularis	d'Orbigny, p. 27, Pl. 2, figs. 21, 22
1845	" "	d'Orbigny; Reuss, p. 34, Pl. VIII, fig. 48.
1854	" "	d'Orbigny; Reuss, p. 68.
1862	" "	d'Orbigny; Reuss, pp. 70, 93.
1878	" "	d'Orbigny; Marsson, p. 144.
1891	" "	d'Orbigny; Beissel, p. 53, Pl. X, figs. 1-9.
1899	" "	d'Orbigny; Egger, p. 117, Pl. 12, figs. 5, 6.
1910	" "	d'Orbigny; Heron-Allen & Earland, p. 421.
1912	" "	d'Orbigny; Franke, p. 279.
1929	Saracenaria "	(d'Orbigny); Cushman & Church, p. 505, Pl. 37, figs. 13, 14.
1941	" "	(d'Orbigny); Cushman & Hedberg, p. 88, Pl. 21, fig. 35a, b.
1941	" "	(d'Orbigny); Marie, p. 111, Pl. X, fig. 115a, b.
1944	" "	(d'Orbigny); Cushman, p. 8, Pl. 2, fig. 5.
1946	" "	(d'Orbigny); Cushman, p. 58, Pl. 28, figs. 1-3.
1951	" "	(d'Orbigny); Bandy, p. 494, Pl. 72, fig. 11.
1953	" "	(d'Orbigny); Hagn, p. 52, Pl. 6, fig. 4.
1963	" "	(Brotzen); Graham & Church, p. 46, Pl. 5, fig. 13.
1968	" "	(d'Orbigny); Sliter, p. 74, Pl. 9, figs. 3, 4.

Test free, initially planispiral, later tendency to become uncoiled, margins acute, periphery occasionally carinate, triangular in transverse section; chambers distinct, increasing rapidly in size, very broad apertural face, widest at inner margin; sutures distinct flush to very slightly constricted; wall finely perforate, smooth; aperture radiate, terminal on peripheral margin.

Max. dimensions: Length 0.81 mm. Width 0.56 mm. Width of apertural face 0.44 mm.

Remarks: As has been pointed out previously there is some confusion between the present species and the Astacolus jarvisi (Brotzen) group. It is thought that S. triangularis (d'Orbigny) is distinct on the basis of its triangular transverse section, whereas Astacolus is defined as being compressed. The broad apertural face, with its widest point at the base is also characteristic of the present species.

Range: Assemblage Zones A-F.

Genus VAGINULINOPSIS Silvestri 1904

Genotype Vaginulina soluta Silvestri var. carinata Silvestri 1898.

Vaginulinopsis scalariformis Porthault, in Donze et al 1970.

Pl. 5, fig. 4.

1970 Vaginulinopsis scalariformis Porthault, in Donze et al, pp. 51-2, Pl. 8, figs. 1,2, t. fig. 3a,b.

Test large, compressed ovoid in cross-section, initial portion tight planispiral coil, rapidly becoming rectilinear, uniserial; chambers distinct, low; sutures distinct, sub-horizontal to sigmoidal, marked by very characteristic transverse septal ridges, which appear to pass all around the circumference of the test; wall robust, calcareous, smooth; aperture radiate, terminally positioned on the peripheral dorsal angle of the final chamber.

Max. dimensions: Length 1.48 mm. Width 0.56 mm.

Remarks: This species, only recently described from southern France by Porthault (1970, 1974), appears to be fairly restricted in its stratigraphic distribution. Porthault was not able to ascertain the full extent of its range and places it well within the lower Santonian. In the U.K. successions the first appearance of the species may be somewhat earlier, in the upper part of the Coniacian. As this appearance is also fairly consistant this species is of limited regional stratigraphic value.

Range: Assemblage Zones C-F.

Family POLYMORPHINIDAE d'Orbigny 1839

Subfamily POLYMORPHININAE d'Orbigny 1839

Genus GLOBULINA d'Orbigny in de la Sagra 1839

Genotype Polymorphina (Globulina) gibba d'Orbigny 1826

Globulina lacrima Reuss 1845

Pl. 5, fig. 5.

1845 Polymorphina (Globulina) lacrima Reuss, p. 40, Pl. 12, fig. 6.

1891 " proteus Beissel, p. 59, Pl. 11, figs. 1-6, Pl. 13, fig. 83, Pl. 12, figs. 9-16 (non 13)

1930 " lacrima Reuss; Cushman & Ozawa, p. 77, Pl. 13, figs. 1, 2.

1946 Globulina " (Reuss); Schijfsma, p. 66, Pl. 7, fig. 2.

1946 " " (Reuss); Cushman, p. 96, Pl. 40, figs. 11, 12.

1957 " " (Reuss); Hofker, p. 170, figs. 212, 213.

1962 " " (Reuss); Barnard, pp. 715-9, t. figs. 1a, b, k, l.

1963 " " lacrima (Reuss); Graham & Church, p. 48, Pl. 5, fig. 15.

1968 " " (Reuss); Sliter, p. 77, Pl. 9, fig. 17, Pl. 10, fig. 1a-c.

Test free, ovoid to sub-globular in outline; chambers indistinct, partially overlapping;sutures indistinct flush with surface, oblique, slightly sigmoidal; wall smooth, relatively thick; aperture radiate, terminal.

Max. dimensions: Length 0.34 mm. Width 0.28 mm.

Remarks: A rare form occuring sporadically throughout the interval studied. The sub-globular form is uncommon, the majority of the individuals being slightly elongate, and possibly transitional with the more slender <u>Globulina prisca</u> Reuss.

Range: Assemblage Zone A.

<u>Globulina prisca</u> Reuss 1863

Pl. 5, fig. 6.

1863	<u>Globulina prisca</u>	Reuss, p. 79, Pl. IX, fig. 8.
1928	<u>Polymorphina minuta</u>	Roemer; Franke, p. 120, Pl. XI, fig. 8a, b.
1930	<u>Globulina prisca</u>	Reuss; Cushman & Ozawa, p. 73, Pl. XII, fig. 6a-c.
1936	" "	Reuss; Brotzen, p. 114, Pl. VII, fig. 11.
1941	" "	Reuss; Marie, p. 168, Pl. XXII, figs. 238a, b, 239a-e.

Test free, slender, slightly elongate pyriform; chambers distinct, partially overlapping, elongate; sutures fairly distinct, oblique, flush with surface to slightly depressed; wall smooth; aperture radiate, terminal.

Max. dimensions: Length 0.63mm. Width 0.31 mm.

Remarks: As noted with <u>G. lacrima</u> (Reuss), individuals of this genus are not common in the English succession. This was noted by Barnard (1962), who was in fact examining material from higher stratigraphic horizons.

Range: Assemblage Zones C-E.

Genus GUTTULINA d'Orbigny in de la Sagra 1839

Genotype Polymorphina (Guttuline) communis d'Orbigny 1826

Guttulina trigonula (Reuss) 1845

Pl. 5, fig. 7.

1845	Polymorphina trigonula	Reuss, p. 40, Pl. XIII, fig. 84.
1845	" damaecornis	Reuss, p. 40, Pl. XIII, fig. 85.
1891	" glommerata	Roemer; Beissel, p. 62, Pl. 12, figs. 2-29.
1930	Guttulina trigonula	Cushman & Ozawa (non Reuss); p. 28, Pl. 4, fig. 2a-c.
1936	" "	(Reuss); Brotzen, p. 113, Pl. VIII, fig. 13a-d.
1946	" "	(Reuss); Cushman, p. 95, Pl. 40, figs. 6, 7.
1957	" "	(Reuss); Hofker, p. 165, fig. 203.
1962	" "	(Reuss); Barnard, p. 721, t. fig. 5.

Test free, small, globular to ovoid in outline, initial end is rounded, often fairly broad; chambers distinct, strongly overlapping, elongate, slightly inflated; sutures distinct, constricted, outlining each chamber; wall smooth, perforate calcite; aperture terminal, radiate.

Max. dimensions: Length 0.54 mm. Width 0.48 mm.

Remarks: This species is recorded sporadically throughout the Coniacian and the lower Santonian.

Barnard (1962) noted that the form referred to Guttulina trigonula (Reuss) by Cushman and Ozawa (1930), is in fact from the Cambridge Greensand and more likely to be related to Guttulina sororia (Reuss). However, Barnards' interpretation of G. sororia is now believed to be incorrect and his species has been compared with G. adherensis (Olszewski) var. cuspidata Cushman & Ozawa (Hart 1970).

Range: Assemblage Zones A-F.

Subfamily RAMULININAE Brady 1884.

Genus RAMULINA Jones in Wright 1875

Genotype Ramulina laevis Jones, in Wright 1875

Ramulina aculeata Wright 1886

Pl. 5, figs. 8, 9, 10.

1886	*Ramulina aculeata*	Wright, p. 331, Pl. 27, fig. 11.
1899	" "	Wright; Egger, p. 135, Pl. 2, fig. 3.
1925	" "	Wright; Franke, p. 80, Pl. VI, fig. 25.
1928	" "	Wright; Franke, p. 124, Pl. XI, figs. 16, 17.
1936	" "	Wright; Brotzen p. 116, t. fig. 38.
1946	" "	(d'Orbigny); Cushman, p. 100, Pl. 43, fig. 11.
1953	" *novaculeata*	Bullard, p. 346, Pl. 46, fig. 26.
1953	" *aculeata*	(d'Orbigny); Hagn, p. 71, Pl. 6, fig. 10.
1964	" "	(d'Orbigny); Loeblich & Tappan, p. C537, fig. 420, 8.
1966	" "	(d'Orbigny); Bartenstein, Bettenstaedt & Bolli, pp. 159-60, Pl. 4, figs. 315-324 (?325-339).
1972	" "	(d'Orbigny); Barnard, p. 390, Pl. 1, fig. 1.
1972	" *wrightii*	Barnard, pp. 390-391, Pl. 1, figs. 2, 3.

Test free, consisting of globular chambers, irregular in shape, and interconnected by long or short tube-like stolons; stolons may have two or more junctions, angles of attachment are also irregular, wall calcareous, spinose ornament normally present; aperture often not seen, occasional constrictions at the end of a stolon may be the site of an aperture.

Max. dimensions: Length 1.38 mm. Width 0.65 mm.
Due to the irregular nature of the test and lack of any indication as to the true direction of growth, the sizes given are only approximate.
Remarks: Despite the work of Loeblich and Tappan (1964) with regards to this particular species, there still appears to be a considerable margin of doubt as to the true authorship.

D'Orbigny's original description of Dentalina aculeata was of material taken from the Tertiary deposits of the Paris Basin, and his figures were of little value in giving a true indication as to the genus. Neither were the figures illustrated by Reuss (1845) some fifteen years later. Thus when Wright defined Ramulina aculeata in 1886 from the Upper Cretaceous of Northern Ireland, the majority of micropalaeontologists working on the Chalk chose to use his species.

In 1949 Loeblich and Tappan suggested that D. aculeata d'Orbigny and R. aculeata Wright were in fact synonymous, and in an attempt to unravel the confusion they re-examined what they believed to be the type material in Paris and re-stated the priority of d'Orbigny's authorship in the Treatise on Invertebrate Paleontology (1964).

There is however a strong possibility that the material examined by Loeblich & Tappan was not the same as that from which D. aculeata d'Orbigny was described. This was postulated by Hart (1970) after examination of a microfilm of d'Orbigny's type material. Hart noted that D. aculeata appeared to be a true Dentalina "quite unlike his type figure". Thus at present, Wright's species would seem to be valid for those individuals found in the Upper Cretaceous, although it is noted that after ninety years of confusion, we have still not finally clarified the situation.

Range: Assemblage Zones A-F.

Ramulina sp. A.

Pl. 5, fig. 11.

Test free, comprising three globular chambers, connected by short, broad stolons; wall calcareous, tuberculate; apertures at the distal end of each chamber.

Max. dimensions: Length 0.42mm. Width 0.35mm.

Remarks: Test very similar to the inflated forms of R. aculeata Wright described above, distinguished by the fact that in this species three very globular chambers are interconnected in very close proximity to each other without the development of long stolons. The surface of the test is also much more tuberculate than in the typical R. aculeata.

This species is rare, the specimen figured being found at the junction of the M. cortestudinarium and M. coranguinum Zones, of Rowe (1900), from Langdon Stairs, Kent.

Range: Assemblage Zone B.

Superfamily BULIMINACEA Jones 1875

Family TURRILINIDAE Cushman 1927

Subfamily TURRILININAE Cushman 1927

Genus PRAEBULIMINA Hofker 1953

Genotype Bulimina ovulum Reuss 1845

Praebulimina reussi (Morrow) 1934 sensu lata

Pl. 5, figs. 12, 13.

1845	Bulimina ovulum	Reuss (non B. ovula d'Orbigny), p. 87, Pl. VIII, fig. 57, Pl. XIII, fig. 73.
1899	" "	Reuss; Egger, pp. 51-52, Pl. 15, fig. 46.
1925	" "	Reuss; Franke, p. 25, Pl. 2, fig. 17.
1928	" "	Reuss; Franke, p. 157, Pl. 14, fig. 14.
1934	" "	Reuss; Cushman & Parker, p. 29, Pl. 5, figs. 10, 11a-b.
1934	Bulimina reussi	Morrow; pp. 195-6, Pl. 29, fig. 2.
1936	Bulimina ovula	Reuss; Brotzen, pp. 125-7, tf. 42, fig. 9.
1936	Bulimina ventricosa	Brotzen, pp. 124-7, Pl. 8, fig. 1a-c, tf. 42, figs. 1-8.
1946	Bulimina reussi	Morrow; Cushman, pp. 120-1, Pl. 51, figs. 1-5.
1947	" "	Morrow; Cushman & Parker, Pl. 19, fig. 31. Pl. 20, figs. 1-5.
1951	Praebulimina reussi	(Morrow); Hofker, p. 144.
1953	Praebulimina reussi	(Morrow); Hofker, p. 27.
1957	" ventricosa	(Morrow); Hofker, pp. 187-8, tfigs. 227, 228.
1961	Bulimina reussi	Morrow; Vasilenko, pp. 174-6, Pl. 38, figs. 2a-b, 7a-b.
1968	Praebulimina "	(Morrow); Sliter, p. 85, Pl. 12, figs. 1, 2.

Test free, usually small, globular and ovoid in shape, roughly circular in section, greatest width across the final whorl above the mid-line of the test; initial chambers small forming an acute apical angle, which may vary from rounded to sub-angular; chamber arrangement triserial throughout, chambers become inflated rapidly, elongate; sutures slightly curved, indistinct and slightly depressed; wall smooth, calcareous, very finely perforate; aperture sub-terminal slit, quite wide and adjacent to the inner margin of the final chamber.
Max. dimensions: Length 0.43 mm. Width 0.30 mm.
Remarks: The appearance of this species in the 250 -500μ fraction towards the base of the lower Santonian as defined by Casey et al (in press) is extremely useful, although it should be noted that it appears in the finer fraction of sieved material well before this, in the upper part of the Coniacian.

Prior to 1934 there existed a problem of nomenclature with regard to this species, when Morrow renamed Praebulimina ovulum (Reuss). Reuss's species was in fact a homonym of Bulimina ovula d'Orbigny, which had been described six years earlier in 1839 from Tertiary deposits of South America.

Included within the synonomy of the present broad group is Praebulimina ventricosa (Brotzen). This species was originally distinguished by the greater inflation in the later chambers which tend to overlap onto earlier stages. This is believed to fit within the broader range in variation present in P. reussi (Morrow), a view that was also suggested by Sliter (1968).

Range: Upper part of Assemblage Zone C- Assemblage Zone F.

Praebulimina obtusa (d'Orbigny) 1840

Pl. 5, fig. 14.

1840	Bulimina obtusa	d'Orbigny, p. 39, Pl. IV, figs. 5, 6.
1891	" laevis	Beissel, p. 66, Pl. XII, figs. 38-43.
1936	Buliminella "	(Beissel); Cushman & Parker, p. 6, Pl. 11, fig. 3a-c.
1936	" "	(d'Orbigny); Brotzen, p. 131, Pl. VIII, fig. 2a, b.
1937	" "	(d'Orbigny); Marie, p. 264.
1941	" "	(d'Orbigny) forma typica; Marie, pp. 198, 9, Pl. XXX, figs. 290a-f, 291a-e.
1941	" "	(d'Orbigny) var. inflata Marie, p. 199, Pl. XXX, fig. 292a-e.
1941	" "	(d'Orbigny) var. laevis (Beissel); Marie, p. 199, Pl. XXX, fig. 293a-e, Pl. XXXI, fig. 294a-e.

Test free, elongate, slightly flaring, basal angle acute, chambers expanding uniformly in size, small; chambers arranged triserially, elongate, slightly inflated; sutures distinct, slightly constricted; wall smooth, perforate and relatively thick; aperture sub-terminal crescentic slit, rising from the interomarginal suture of the final chamber.

Max. dimensions: Length 0.37 mm. Width 0.22 mm.

Remarks: This species has been placed within the genus Praebulimina following the works of Hofker (1957) and Loeblich & Tappan (1964), the latter commenting that many of the early Cretaceous species of Buliminella should in fact be included in the genus Praebulimina.

Range: Assemblage Zones A-F.

Praebulimina parva (Franke) 1928

Pl. 5, fig. 15.

1928 Bulimina parva Franke, p. 157, Pl. XIV, fig. 13.

Test free, small, slender, flaring gradually, almost pyriform in outline, chamber arrangement triserial throughout, chambers elongate, slender distinct, strongly overlapping; sutures, distinct, compressed, outlining the later chambers well; wall smooth, perforate; aperture sub-terminal arc-shaped, slit.

Max. dimensions: Length 0.34 mm. Width 0.14 mm.

Remarks: A distinctive species, but as yet only recorded from the Upper Senonian of Germany (Franke 1928). It is interesting to note that the small size is quite characteristic as Franke records 0.34 mm. for the length and 0.12 mm. for the width, figures quite consistant with those taken for examples from southern England.

Range: Assemblage Zones C-E.

Genus PYRAMIDINA Brotzen 1948.

Genotype Bulimina? curvisuturata Brotzen 1940

Pyramidina cf. buliminoides (Brotzen) 1936

Pl. 6, fig. 1.

1936 Reussella (?) buliminoides Brotzen, pp. 137-8, Pl. VIII, fig. 8a-c, t. fig. 48.

1957 " buliminoides Brotzen; Hofker, p. 207, figs. 251-3.

1961 Pyramidina " (Brotzen); Vasilenko, p. 178, Pl. XXXVIII, fig. 15a-d.

Test free, small, flaring, triserial throughout, marginal angles rounded; chambers increasing uniformly in size, inflated, distinct, sub-globular on outer margins, slightly overlapping; sutures distinct, slightly depressed; wall smooth, perforate calcite; aperture sub-terminal, simple slit perpendicular to the interomarginal suture of the final chamber.

Max. dimensions: Length 0.23 mm. Width 0.13 mm.

Remarks: The specimens of P. buliminoides illustrated by Brotzen (1936) and Vasilenko (1961) are too small to give precise details. In the absence of type material for comparison, the specimens described are referred to P. cf. buliminoides.

There are some similarities with the American species P. triangularis (Cushman & Parker), although as Sliter (1968) points out, this form is more distinctly flaring and more coarsely perforate. The two are distinct but obviously very closely related.

Range: Top of Assemblage Zone D to Assemblage Zone F.

Family EOUVIGERINIDAE Cushman 1927

Genus EOUVIGERINA Cushman 1926

Genotype Eouvigerina americana Cushman 1926

Eouvigerina aculeata (Ehrenberg) 1854

Pl. 6, figs. 2,3

1854 Loxostomum aculeata Ehrenberg, p. 22, Pl. 27, figs. 21, 22, Pl. 28, fig. 26.

1892 Textularia serrata Chapman, p. 515, Pl. 15, fig. 7.

1910 Sagrina cretacea Heron-Allen & Earland, p. 423, Pl. 8, figs. 8-10.

1926 Eouvigerina americana Cushman, pp. 4, 5, Pl. 1, fig. 1a-c.

1931	" "	Cushman; Cushman, p. 45, Pl. 7, fig. 11a,b.
1932	" cretacea	(Heron-Allen & Earland); Macfadyen, p, 493, Pl. 35, fig. 23.
1936	" americana	Cushman; Brotzen, pp. 123-4, Pl. 9, fig. 4a-c.
1941	" aspera	(Marsson) var. laevigata Marie; Marie, p. 193, Pl. XXIX, fig. 284a-c.
1941	" "	(Marsson) var. denticulocarinata Marie; Marie, 193-4, Pl. XXIX, fig. 285a-c.
1946	" americana	Cushman; Cushman, pp. 12, 115-6, Pl. 49, figs. 4a-c, 5a-c.
1948	" cretacea	(Heron-Allen & Earland); Williams-Mitchell, pp. 103-4, Pl. 9, fig. 4.
1951	" americana	Cushman; Loeblich, pp. 106, 109-10, Pl. 12, fig. 9.
1957	" aculeata	(Ehrenberg); Hofker, pp. 276-5, t. figs. 327-8.
1957	" americana	Cushman; Montanaro-Gallitelli, p. 148, Pl. 34, figs. 1-5.
1964	" serrata	(Chapman); Barr & Cordey, pp. 307-8, Pl. 49, figs. 8, 9.
1964	" aculeata	(Ehrenberg); Loeblich & Tappan, pp. C556-7, fig. 440. 1-3.
1970	" "	(Ehrenberg); Porthault, in Donze et al, p. 57, Pl. 8, fig. 25.

Test free, biserial, becoming more irregular in later stages; chambers distinct, uninflated initially, becoming slightly inflated, angular and truncated later; sutures distinct, flush becoming later depressed, curved; wall smooth, finely perforate, calcareous, occasional slightly nodose on the marginal flange, which is not always fully developed; aperture terminal slit, surrounded by a low phialine lip, at the end of a short apertural neck.

Max. dimensions: Length 0.34 mm. Width 0.19mm.

Remarks: As can be seen from the long synonomy, this species has had a diverse career, stemming from an initial influx of varying trivial names. It would appear however that a good deal of duplication has taken place, and the above list follows the lead given by Barr & Cordey (1964) and Loeblich & Tappan (1964) in attempting to simplify this problem of nomenclature, in what appears to be a single species.

A thorough examination was made of those specimens housed in the British Museum (Natural History), these being taken from the collections of Chapman (P4547), Heron-Allen & Earland (P48937) Williams-Mitchell (P50313) and Barr & Cordey (P44966). Comparison was made between these and specimens from the present study and all were found to be conspecific.

Loeblich & Tappan (1964) point out that E. americana Cushman is synonymous with E. aculeata (Ehrenberg), extending the list to material described from the U.S.A.

Marie (1941) further complicates the taxonomy by introducing four new varieties of E. aspera (Marsson), two of which are thought to be synonymous with E. aculeata.

Furthermore, on examination of Marsson's figure of 1878, his species seems to bear little similarity to either that of Ehrenberg and, possibly more importantly, to those specimens illustrated by Marie.

Williams-Mitchell (1948) noted the stratigraphic value of this species, in its appearance mid-way through the M. cortestudinarium Zone of southern England. This correlates well with the range noted in the present work.

Range: Top of Assemblage Zone A - Assemblage Zone F.

Eouvigerina stormi Brotzen 1936

Pl. 6, fig. 4.

1929 Sagrina cretacea Storm (non Heron-Allen and Earland) p. 53, fig. 9.

1936 Eouvigerina stormi Brotzen; Hofker, pp. 273-4, t. fig. 326.

Test small, slightly flaring, biserial throughout, margins truncated; chambers distinct, flat, slightly oblique in arrangement; sutures distinct, oblique, flush to slightly raised, at the margins continuing outwards to form a small marginal septa; wall smooth, calcareous; aperture terminal slit, with a small raised lip.

Max. dimensions: Length 0.19mm. Width 0.13 mm.

Remarks: An extremely small form which is not particularly abundant. It is related to E. aculeata (Ehrenberg), but thought to be distinct, due to the presence of the marginal septa, which are not seen in the early stages of Ehrenberg's species. Brotzen (1936) clarified the taxonomy by erecting E. stormi as a nomen novum for Storms mis-identification of E. cretacea (Heron-Allen & Earland).

Range: Assemblage Zone A- base of Assemblage Zone D.

<u>Eouvigerina</u> sp. C.

Pl. 6, fig. 5.

Test free, small, biserial throughout, longitudinal central axis about which chambers are arranged is slightly twisted, margins rounded; chambers distinct, elongates, slightly pyriform, final chamber centrally positioned; sutures slightly depressed, oblique, straight to slightly curved; wall finely perforate, calcareous, smooth; aperture terminal positioned at the end of a short neck.

Max. dimensions: Length 0.31 mm. Width 0.12 mm.

Remarks: This species was difficult to place taxonomically, however the presence of a distinct apertural neck with a lip and the biserial chamber arrangement gave it a position within the genus <u>Eouvigerina</u>.

The stratigraphic range of the species is distinctive, the consistency of its first appearance allowing its use in regional correlation. <u>Eouvigerina</u> sp. C. has been found over a wide area including the Isle of Wight, Kent, and Norfolk.

Range: Assemblage Zones D - F.

Family BULIMINIDAE Jones 1875

Subfamily PAVONINAE Eimer & Fickert 1899

Genus REUSSELLA Galloway 1933

Genotype Verneuilina spinulosa Reuss 1850

The Genus REUSSELLA Galloway 1933

The definition of the genus Reussella Galloway as given by Loeblich & Tappan (1964) in the Treatise on Invertebrate Paleontology reads as follows:-

> "Test triserial and triangular throughout, gradually enlarging; wall calcareous, coarsely perforate; aperture basal in final chamber, with internal tooth plate.(Reussella is restricted here to include only sharply angular species, commonly with carinate or spinose angles, coarsely perforate wall, and complex tooth plate. Upper Cretaceous species that have been previously referred to Reussella are here regarded as belonging to Pyramidina, differing in their less angular margin, finely perforate wall, and simpler tooth plate) M. Eocene (Lutetian) - Recent."

Following from this, all those specimens recorded here as Reussella should be included in the genus Pyramidina. However, the description of individuals with "less angular margins" and a "finely perforate wall" from the Upper Cretaceous does not appear to hold true for the majority of specimens encountered during the course of this work.

The species Reussella kelleri, described, and well illustrated, by Vasilenko (1961) has, in his figures, distinctly angular margins which appear to be carinate and in some places spinose. This species has been encountered in large numbers in the British succession and has been found to be angular, coarsely spinose on occasions, and also very coarsely perforate (see Pl. 6, fig. 8).

There is a tooth plate present and as the degree of complexity required for the designation of the genus is difficult to assess, it is felt that the specimens examined fall well within the definition of Reussella.

There is a further species present in the Upper Cretaceous of this country which supports the conclusion made above. Reussella szajnochae (Grzybowski) is encountered in sediments from the lower Santonian through to the Danian (de Klasz & Knipscheer 1954), the subspecies R. szajnochae praecursor being recorded in the succession under study. Although the margins are sub-angular to rounded in early forms, it seems that as this species evolves through the Upper Cretaceous the sutures become much more sharply raised resulting in distinctly angular margins. The use of this character in the generic definition is therefore questioned.

It is thought that during the Senonian there is a distinct evolutionary pattern present, which includes such species as R. kelleri Vasilenko, R. szajnochae (Grzybowski) and R. cushmani Brotzen. This pattern is illustrated in Figure 4.3, to clarify the situation encountered in southern England.

Reussella cf. cushmani Brotzen 1936

Fig. 4:4.

1936	Reussella cushmani	Brotzen, p. 135, Pl. VIII, fig. 7a-c, t. fig. 47.
1948	" "	Brotzen; Williams-Mitchell, p. 104, Pl. 9, fig. 9.

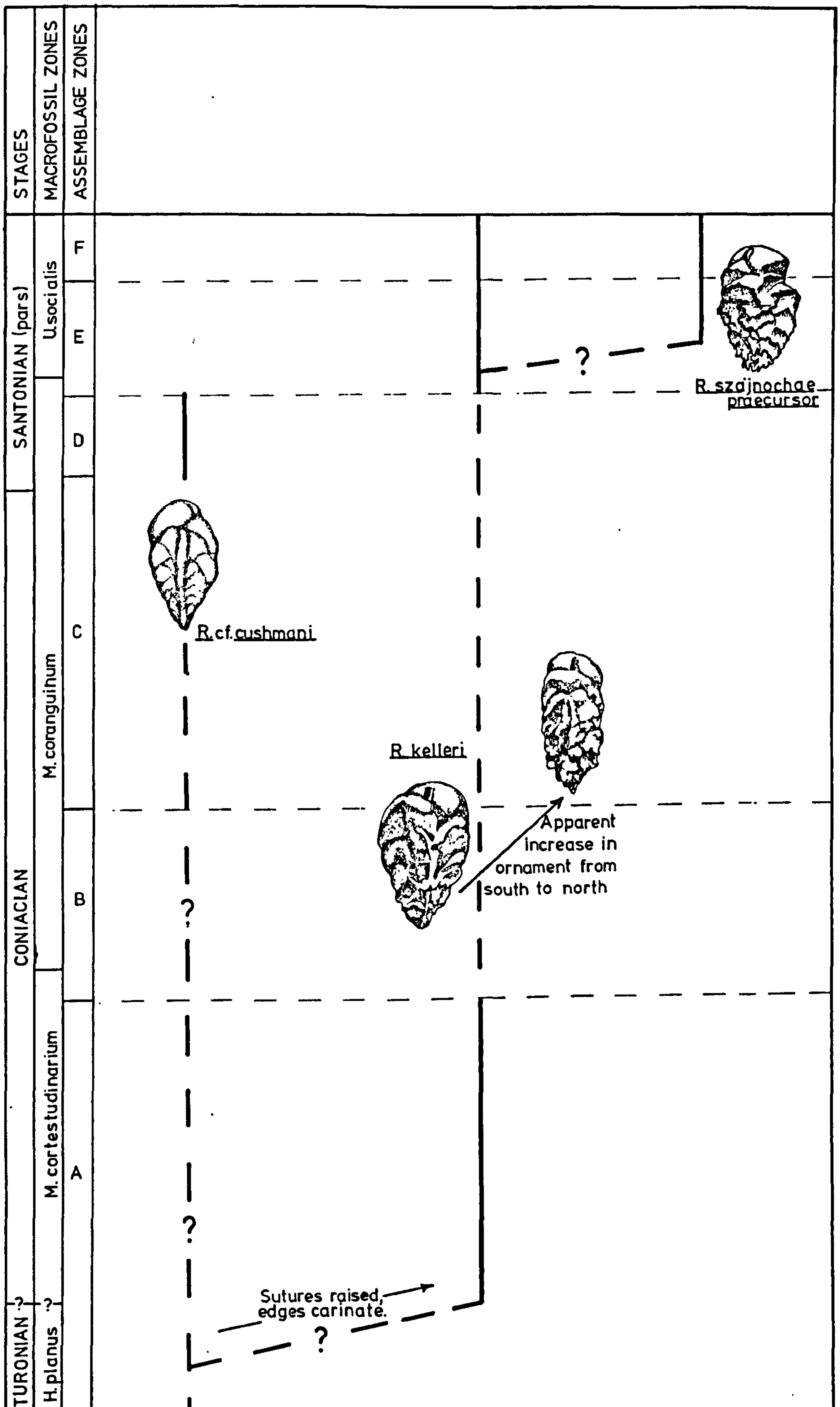


Fig.4:3 Lower Senonian evolutionary trends in the genus Reussella

Test free, elongate, triserial throughout, sub-triangular outline, edges sub-angular to rounded; chambers distinct, tria-angular, strongly over-lapping; sutures flush to slightly raised, curved; wall calcareous, smooth, finely perforate; aperture interomarginal loop.

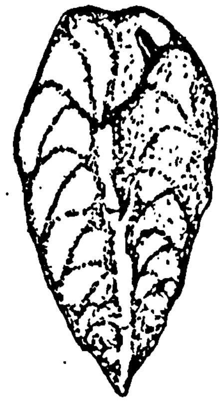
Max. dimensions: Length 0.42 mm. Width 0.23 mm.

Remarks: This species, although previously recorded from the English succession by Williams-Mitchell (1948), is not common, and it is possible that many of the specimens identified as R. cushmani Brotzen by that author should be included in the species R. kelleri. It is acknowledged that the specimen of R. cushmani figured in 1948, and housed in the British Museum (BMNH No. P50314), does fit well within that species, it is also pointed out that other material, from the Portsdown borehole assemblages, located in the Williams-Mitchell collection, is more correctly assigned to Vasilenko's species.

The distribution noted by Williams-Mitchell is also of particular note as this species appears for the first time at the base of the M. cortestudinarium Zone, a level critical for other members of the genus in this country.

Range: Assemblage Zone A-E.

Fig. 4:4
Reussella cf. cushmani



<u>Reussella kelleri</u> Vasilenko 1961

Pl. 6, figs. 6, 7, 8.

1935 <u>Reussella aff. spinulosa</u> (Reuss) Keller, p. 550, Pl. 11, figs. 9 - 11.

1961 <u>" kelleri</u> Vasilenko, pp. 176-8, Pl. XXXVIII, figs. 3-5, 12, 13.

1975 <u>" "</u> Vasilenko; Robaszynski, p. 19, fig. 2.

Test free, sub-triangular in outline, triserial throughout, edges sharply rounded to angular; chambers distinct triangular, strongly over-lapping, becoming lobate in later stages; sutures distinct, curved, often raised becoming broadly limbate; wall calcareous, perforate, often coarsely, slightly rugose on the side races, margins spinose, occasionally developing small flanges which project from the edges; apertural slit, perpendicular to the inner margin of the final chamber, surrounded by a slightly raised lip, tooth plate developed.

Max. dimensions: Length 0.60 mm. Width 0.34 mm.

Remarks: The distribution of this species is important as the first appearance is used to define the base of Assemblage Zone A in this investigation. The wider stratigraphic significance of this boundary is discussed later, although it may be mentioned here that Robaszynski (1975) used this species to define the base of the Coniacian in the region of Lille, France, and he has since confirmed (pers. comm.) that specimens from the same level in this country are identical to his own.

The detailed distribution of this species in the English Chalk has been shown to be quite unusual in the two continuous successions of S.E. Kent and the Thames Barrier Site Investigation at Woolwich.

R. kelleri is common in the 250 μ - 500 μ fraction at the base of each succession, although approximately 20 metres higher it is only found in the fine sieve fraction. It appears again in the larger size fraction sporadically through the succession until the base of Assemblage Zone E, where they occur again in some abundance, helping to define the assemblage zone boundary.

This species is also recorded more commonly in the samples examined from Norfolk, and these specimens tend to be larger and more ornate than those noted from sections further to the south.

Range: Assemblage Zones A-F.

Reussella szajnochae (Grzybowski) praecursor
De Klasz & Knipscheer 1954
Pl. 6, fig. 9.

1931 Pseudouvigerina sp. (?). Cushman, p. 40, Pl. 6, fig. 1a-c.

1954 Reussella szajnochae (Grzybowski) praecursor de Klasz & Knipscheer, pp. 603-4, Tab. p. 605, fig. 1a-c.

Test free, triangular in transverse section, triserial throughout, expanding gradually in size; chambers distinct, low, sub-triangular, distinctly over-lapping; sutures raised, becoming limbate, oblique to slightly curved; wall calcareous, smooth, perforate, occasionally becoming slightly spinose along the lower edges; apertural slit, situated mid-way along the inner margin of the final chamber.

Max. dimensions: Length 0.47mm. Width 0.29mm.

Remarks: This species has only been encountered in samples from the basal Uintacrinus socialis Zone, and therefore first appears well within the Santonian (Casey et al. in press). De Klasz & Knipscheer (1954) note that they have found specimens in material from Taplow, Buckinghamshire. Samples from the latter locality has been processed by the author and specimens identical to those illustrated from Germany have been found.

Range: Assemblage Zone F.

Superfamily DISCORBACEA Ehrenberg 1838

Family DISCORBIDAE Ehrenberg 1838

Subfamily BAGGININAE Cushman 1927

Genus VALVULINERIA Cushman 1926

Genotype Valvulineria californica Cushman 1926

Valvulineria lenticula (Reuss) 1845

Pl. 6, figs. 10,11.

1845	Rotalia lenticula	Reuss, p.35, Pl.XII, fig.17.
1860	" "	Reuss; Reuss, p.221.
1899	Discorbina "	(Reuss); Egger, p.166, Pl. XVIII, figs. 22-24.
1925	Anomalina "	(Reuss); Franke, p.87, Pl.VII, fig.15.
1926	Rotalia cretacea	Carsey, p.48, Pl.5, fig.7a,b.
1928	Anomalina lenticula	(Reuss); Franke, p.183, Pl.XVI, fig.11a-c.
1929	Gyroidina depresse	Cushman & Church, p.515, Pl.41, figs. 4-6.
1936	Valvulineria lenticula	(Reuss); Brotzen, pp.151-3, Pl.11, fig.5a-c, t. figs. 54,55.

1941	Ceratobulimina lenticula	(Reuss); Marie, pp. 226-7, Pl. XXXV, figs. 326-8.
1942	Gavelinella cretacea	(Carsey); Brotzen, p. 54.
1946	Valvulineria "	(Carsey); Cushman, p. 138, Pl. 57, fig. 8a-c.
1951	" "	(Carsey); Bandy, p. 504, Pl. 74, fig. 1a-c.
1957	Valvulineria lenticula	(Reuss); Harris & McNulty, pp. 866-7, Pl. 97, figs. 1-5.
1961	" "	var. lenticula (Reuss); Vasilenko, p. 43, Pl. VIII, fig. 1a-c.
1973	" "	(Reuss); Koch, p. 211.

Test free, low trochospiral, biconvex, periphery rounded; chambers indistinct except in later stages, increasing gradually in size; sutures distinct in later stages, earlier ones poorly visible, radial, straight, curving backwards slightly at the margin, spiral suture distinct and open in the last two chambers; wall perforate calcareous, smooth; aperture narrow slit-like opening, along the inner margin of the final chamber, on the umbilical side; umbilical area covered by a distinct apertural flap.

Max. dimensions: Diameter 0.42 mm. Thickness 0.22 mm.

Remarks: Harris & McNulty (1957) devoted a complete paper to this species and the variations encountered. That detailed work gives a full synonomy, together with a very detailed description of the species.

Valvulineria lenticula (Reuss) is very closely related to Valvulineria plummerae Loetterle, and Vasilenko (1961) includes the latter as a variety of the former. The important distinction between the two species is the width towards the periphery, which in V. plummerae is quite broad, when viewed from the side, whereas

V. lenticula is more tapered and more acutely angled. Very rare examples of specimens approaching the V. plummerae type have been found, but these were considered to be early transitional varieties, and have been retained within the present species.

Range: Assemblage Zones A-F.

Superfamily GLOBIGERINACEA Carpenter, Parker & Jones 1862

Family HETEROHELICIDAE Cushman 1927

Subfamily HETEROHELICINAE Cushman 1927

Genus HETEROHELIX Ehrenberg 1843

Genotype Spiroplecta americana Ehrenberg 1844

Heterohelix globulosa (Ehrenberg) 1840

Pl. 6, figs. 12,13.

1840	Textularia globulosa	Ehrenberg, p. 135, Pl. 4, figs. 2,4,5,7,8.
1845	" "	Reuss; Reuss, p. 39, Pl. XII, fig. 23.
1854	" "	Ehrenberg; Ehrenberg, Pl. 21, fig. 87
1860	" globifera	Reuss, p. 232, Pl. 13, figs. 7,8.
1892	" decurrens	Chapman, p. 515, Pl. 15, fig. 6
1899	Gumbelina globulosa	(Ehrenberg); Egger, p. 32, Pl. 14, fig. 43.
1925	Textularia globifera	Reuss; Franke, p. 11, Pl. 1, fig. 13.
1928	" globulosa	Ehrenberg; Franke, p. 134, Pl. 12, fig. 11.

1932	Pseudotextularia globulosa	(Ehrenberg); Macfadyen, Pl. 35, fig. 22.
1934	Gumbelina globulosa	(Ehrenberg); Morrow, p. 194, Pl. 29, fig. 18a, b.
1946	" "	(Ehrenberg); Cushman, pp. 105-6, Pl. 45, figs. 9-15.
1946	" spinifera	Cushman, p. 108, Pl. 46, fig. 15a, b.
1948	" globulosa	(Ehrenberg); Williams-Mitchell, p. 99, Pl. 9, fig. 2.
1951	" "	(Ehrenberg); Loeblich, p. 108, Pl. 12, figs. 4, 5.
1953	" "	(Ehrenberg); Hagn, p. 73, Pl. 6, figs. 16, 17.
1957	" "	(Ehrenberg); McGugan, p. 339, Pl. 32, fig. 18.
1957	Heterohelix "	(Ehrenberg); Montanaro-Gallitelli, p. 137, Pl. 31, figs. 12-15.
1962	" "	(Ehrenberg); Graham & Church, pp. 61-2, Pl. 7, fig. 11a, b.
1964	" "	(Ehrenberg); Barr & Cordey, pp. 306-7, Pl. 49, fig. 4.
1965	" "	(Ehrenberg); Takayanagi, pp. 195-6, Pl. 20, fig. 1a, b.
1966	" "	(Ehrenberg); Barr, p. 503, Pl. 78, figs. 5, 6.
1967	" "	(Ehrenberg); Pessagno, p. 260, Pl. 87, figs. 5-9, 11-13.

1967 ___"___"___ (Ehrenberg); Bandy, p. 23, t. fig. 12.
1968 ___"___"___ (Ehrenberg); Sliter, pp. 94-5, Pl. 14, figs. 1-3.
1969 ___"___"___ (Ehrenberg); Douglas, pp. 157-8, Pl. 11, fig. 12.

Test small, initially planispirally coiled, rapidly becoming biserial, tapering from the widest point across the two final chambers; chambers globular, increasing in size rapidly in the adult stages; sutures distinct, constricted; wall smooth, to very finely striate, calcareous, perforate, thin; aperture low semi-circular arch on the inner margin of the final chamber, often with a very slightly raised lip.

Max. dimensions: Length 0.36 mm Width 0.21 mm.

Remarks: A much used, discussed, and maligned species, resulting from a brief original description and type figures which are of very little value. Douglas & Rankin (1969) give a valuable discussion concerning this species and its nearer relatives, including H. reussi Cushman with which they suggest it may be synonymous. They qualify this by saying that until the true nature of the external characters of H. globulosa are known, the problem will remain unsolved.

The present author is in agreement with this statement, but it is thought that there are at least two species present in the Micraster zones of the English Chalk.

Range: Assemblage Zones A-F.

<u>Heterohelix reussi</u> (Cushman) 1938

Pl. 6, figs. 14,15.

1938	<u>Gumbelina reussi</u>	Cushman, p. 11, Pl. 2, figs. 6-9.
1946	" "	Cushman, p. 104, Pl. 44, figs. 18a, b, 19.
1967	<u>Heterohelix</u> "	(Cushman); Pessagno, p. 263, Pl. 85, figs. 1-9, Pl. 86, figs. 1-2.
1969	" "	(Cushman); Douglas, pp. 158-9, Pl. 11, fig. 15.
1969	" "	(Cushman); Douglas & Rankin, pp. 191-2, fig. 5A, B.
1970	" "	(Cushman); Porthault, in Donze et al, pp. 61-2, Pl. 9, figs. 1-3.

Test free, small, initial chambers planispiral, rapidly becoming biserial, widest point across last two chambers; chambers globular, rapidly increasing in size; sutures strongly constricted, creating sub-triangular depressions down the central suture; wall calcareous, perforate, rugose to slightly striate; aperture interomarginal semi-circular arch.

Max. dimensions: Length 0.32 mm. Width 0.18 mm.

Remarks: Distinguished from <u>H. globulosa</u> (Ehrenberg) by the presence of distinct triangular depressions between the chambers, situated along the central suture. <u>H. globulosa</u> appears to be more compressed laterally, with the chambers more closely packed against each other, while this is not the case in <u>H. reussi</u>, where depressions are present between the adjacent chambers.

Range: Assemblage Zones A - F.

Family PLANOMALINIDAE Bolli, Loeblich & Tappan 1957

Genus GLOBIGERINELLOIDES Cushman & Ten Dam 1948

Genotype Globigerinelloides algeriana Cushman & Ten Dam 1948

Globigerinelloides asperus (Ehrenberg) 1854
Pl. 7, fig. 1.

non 1854 Rotalia aspera Ehrenberg, p. 24, Pl. 27, figs. 57, 58, Pl. 28, fig. 42, Pl. 31, fig. 44.

1854 Phanerostomum asperum Ehrenberg, p. 23, Pl. 30, fig. 26a, b.

1891 Rotalia aspera Ehrenberg; Beissel, p. 73, Pl. 14, figs. 1-6.

1892 Globigerina aequilateralis (non Brady); Chapman, p. 517, Pl. 15, fig. 14.

1910 " " (non Brady); Heron-Allen & Earland, p. 424, Pl. 8, figs. 11, 12.

1936 Globigerinella aspera (Ehrenberg); Brotzen, p. 170, Pl. 13, fig. 2.

1946 " " (Ehrenberg); Schijfsma, pp. 94-6, Pl. 6, fig. 8.

1951 " " (Ehrenberg); Bandy, p. 508, Pl. 75, fig. 3.

1960 " " (Ehrenberg); Belford, p. 91, Pl. 25, figs. 4-6.

1962 Planomalina " (Ehrenberg); Barr, pp. 561, 563, Pl. 69 fig. 4a, b.

1963 " (Globigerinelloides) aspera (Ehrenberg); van Hinte, p. 97, Pl. 12, figs. 2a, 3.

1963 Globigerinella aspera (Ehrenberg); Graham & Church, pp. 64-5, Pl. 7, fig. 17a-c.

1964 Globigerinelloides aspera (Ehrenberg); Barr & Cordey, p. 309.

1967 ______ " ______ aspera aspera (Ehrenberg); Bandy, p. 12, t. fig. 5.

1967 ______ " ______ asperus (Ehrenberg); Pessagno, pp. 274-5, Pl. 60, figs. 4,5.

Test free, small, planispiral, biumbilicate, partially evolute, two to three whorls, only the final one is fully visible, chambers inflated, globular giving a lobate. periphery, five to six chambers in the final whorl; sutures deeply constricted, radial, straight; wall perforate, calcareous, finely hispid; aperture low, broad equatorial arch, extending back towards the umbilicus on both sides, raised lip on the upper edge of the aperture.

Max. dimensions: Diameter 0.25 mm. Thickness 0.14 mm.

Remarks: This common species may be easily mistaken for G.ehrenbergi (Barr) from which it is distinguished by having fewer chambers in the final whorl. It also appears to be more finely hispid, although this latter feature is rather variable.

Range: Assemblage Zones A - F.

Globigerinelloides ehrenbergi (Barr) 1962

Pl. 7, fig. 2.

1962 Planomalina ehrenbergi Barr, p. 563, Pl. 69, fig. 1a,b.

1967 Globierinelloides ehrenbergi (Barr); Pessagno, p. 276.

Test free, small, planispiral, shallow biumbilicate, roughly circular in outline, loosely coiled partially evolute, of two whorls, only the final one being visible, chambers distinct, globular; sutures radial, constricted, straight to slightly curved; aperture low, equatorial arch, extending back towards the umbilicus on both sides, distinct porticus partially covering the first chamber of the final whorl.

Max. dimensions: Diameter 0.25 mm. Thickness 0.09 mm.

Remarks: Barr (1962) records this species as ranging to within 50 feet of the top of the M. coranguinum Zone at Culver Cliff, using the zonation outlined by Rowe (1908). However, as described in more detail later, it is though that Rowe's upper boundary of this zone may be much too high, thus giving G. ehrenbergi (Barr) a range throughout the M. coranguinum Zone, a distribution which is consistant with other sections in southern England.

Range: Upper part of Assemblage Zone B to Assemblage Zone D.

Globigerinelloides rowei (Barr) 1962

Pl. 7, fig. 3.

1962 Planomalina rowei Barr, p. 564, Pl. 69, fig. 2a,b.

Test free, small, planispiral, partially evolute, loosely coiled, biumbilicate, both shallow, approximately two whorls; chambers distinct, globular, final chamber becoming slightly elongate, giving the periphery a vaguely quadrilateral outline, four to five chambers in the final whorl; sutures distinct, constricted, radial, straight; wall thin, calcareous, finely hispid; aperture equatorial, interomarginal, low arch extending back along both sides towards the umbilici, upper edge with a slightly raised lip which may develop into portici on the sides.

Max. dimensions: Diameter 0.22 mm. Thickness 0.10 mm.

Remarks: The range for this species given by Barr (1962) for the M. coranguinum Zone extending rarely into the Marsupites testudinarius Zone, is consistant with that found in other parts of southern England, it is quite distinctive morphologically, although it is never found in any abundance.

Range: Assemblage Zone C to lower part of Assemblage Zone E.

Family ROTALIPORIDAE Sigal 1958

Subfamily HEDBERGELLINAE Loeblich & Tappan 1961

Genus HEDBERGELLA Bronniman & Brown 1958

Genotype Anomalina lorneiana d'Orbigny var. trochoidea Gandolfi 1942

Hedbergella brittonensis Loeblich & Tappan 1961

Pl. 7. figs. 4,5.

1934 Globigerina cretacea d'Orbigny; Morrow, p. 198, Pl. 30, figs. 7,8, 10a,b.

1961 Hedbergella brittonensis Loeblich & Tappan, pp. 274-5, Pl. 4, figs. 1-8.

1961 " portsdownensis (non Williams-Mitchell); Loeblich & Tappan, p. 277, Pl. 5, fig. 3

1967 " brittonensis Loeblich & Tappan; Pessagno, p. 282, Pl. 52, figs. 9-12.

1967 " portsdownensis (non Williams-Mitchell); Bandy, p. 8, t. fig. 3.

1969 " " (non Williams-Mitchell); Douglas & Rankin, pp. 194-6, fig. 7A-F.

1969 " cf. amabilis Loeblich & Tappan; Douglas & Rankin, pp. 196-7, fig. 8A-C.

Test free, coiled in a moderately high trochospire, five chambers in the final whorl, the final chamber becoming situated in a position over, and masking the umbilical region; chambers distinct, inflated, globular; sutures depressed, straight, radiate; wall calcareouse to more finely hispid, the final chamber often lacking in ornament; aperture umbilical to extra-umbilical, with a slightly raised lip on the upper margin.

Max. dimensions: Diameter 0.58 mm. Thickness 0.44 mm.

Measured from the lower edge of the final chamber.

Remarks: A long ranging species, probably arising from the earlier H. delrioensis (Carsey) stock (Pessagno 1967), as numerous transitional forms between the two species have been noted, including a large number of the specimens examined in the present study. The presence of these transitional forms probably accounts for much of the confusion between H. brittonensis Loeblich & Tappan and its predecessor H. portsdownensis (Williams-Mitchell). As Hart has already commented (1970), the type specimen of H. portsdownensis (BMNH No. P. 38283) when examined closely, is not the high spired form one is led to believe from the type figures (Williams- Mitchell, 1948). In all probability it is an early transitional form from H. delrioensis. Thus, all those later publications which have recorded high spired forms of H. portsdownensis are here listed within the synonymy of H. brittonensis.

Included within the present synonymy is H. cf. amabilis Douglas & Rankin (1969), this has been done because of the similarity of the figured specimens to H. brittonensis and the total lack of the characteristic chamber elongation typically noted in H. amabilis Loeblich & Tappan. The lack of this character is even noted by Douglas & Rankin in their discussion of the species.

A much more detailed account of the evolutionary relationships of H. brittonensis has been given by Carter & Hart (in press, B).

Range: Assemblage Zones A-E.

Hedbergella planispira (Tappan) 1940

Pl. 7, fig. 6.

1940 Globigerina planispira Tappan, p. 12, Pl. 19, fig. 12.

Test free, small, low trochospire, almost planispiral, six to eight chambers in the final whorl; chambers inflated, globular; sutures straight, radial, constricted; wall calcareous, perforate, slightly rugose;

aperture simple umbilical to extra-umbilical arch.

Max. dimensions: Diameter 0.26 mm. Thickness 0.13 mm.

Remarks: Numerous small specimens belonging to the genus Hedbergella have been extracted from samples throughout which could not be classified as juveniles from the H. delrioensis - H. brittonensis lineage. Their general morphology is more akin to that of H. planispira Tappan, a form more usually thought of as ranging between the Albian through to the upper part of the Turonian. The present form is believed to be a further continuation of this lineage through the Coniacian.

Range: Assemblage Zone A to the base of Assemblage Zone C.

Family GLOBOTRUNCANIDAE Brotzen 1942

Genus GLOBOTRUNCANA Cushman 1927

Genotype Pulvinulina arca Cushman 1926

As was stated at the beginning of the Systematic Micropalaeontology, the classification used here is based, almost entirely on that of Loeblich and Tappan (1964). This policy has been maintained in connection with the Globotruncanidae. This has led to the inclusion of several species within this family which were referred to the Marginotruncanidae n. fam. by Pessagno (1967). A fuller discussion regarding this group of the Globigerinacea is given later, suffice it to say at present that the foundation on which Pessagno's family of the Marginotruncanidae is based is believed to be invalid. This being due to the fact that the family is based on the genus Marginotruncana (Hofker 1956), which in turn is based on the type species Rosalina marginata Reuss 1845, a species which is firmly believed to have been misidentified by Hofker (1956), in his erection of the genus.

Globotruncana cf. angusticarinata (Gandolfi) 1942

Pl. 7, figs. 7,8. Pl. 9, fig. 1.

1942 Globotruncana linnei (d'Orbigny) var. angusticarinata Gandolfi, pp. 126, 150, 153, Pl. 4, figs. 17, 30, t. fig. 46.

Test free, trochospiral, biconvex more strongly on the spiral side, narrow double keel present around the whole of the periphery; chambers angular truncated, very slightly inflated, petaloid to slightly elongated, five to six in the final whorl; sutures elevated on both sides, curved becoming limbate on the umbilical side; wall calcareous, perforate except over the keels which appear to be beaded; umbilcus wide often filled with chalk thus apertural details difficult to determine.

Max. dimensions: Diameter 0.61 mm. Thickness 0.34 mm.

Remarks: An uncommon species in the southern England succession, found on only a few occasions in the present study, and then very poorly preserved. For this reason the species identification has not been confirmed.

Range: Assemblage Zone A-B.

Globotruncana bulloides Vogler 1941

Pl. 7, figs. 9, 10, 11, Pl. 15, fig. 2.

1941 Globotruncana linnei (d'Orbigny) subsp. bulloides Vogler, p. 287, Pl. 23, figs. 32-39.

1944 ?Globotruncana lapparenti bulloides Vogler; Bolli, pp. 231-2, t. figs. 17, 18, Pl. 9, fig. 12.

1951 " " " Vogler; Bolli, pp. 190, 194, fig. 1.

1955 " bulloides " Vogler; Gandolfi, p. 32, Pl. 1, fig. 91-c.

1957 " marginata (Reuss); Edgell, p. 114, Pl. 2, figs. 4-6.

1962 " lapparenti bulloides Vogler; Herm, pp. 84, 85, Pl. 6, fig. 6.

1962 ______"______ marginata (Reuss); Barr, (part), pp. 574-5, Pl. 70, fig. 3a-c, Pl. 72, figs. 7, 8a-c.

1962 ______"______ culveriensis Barr, pp. 569-570, Pl. 71, fig. 1a-c.

1962 ______"______ lapparenti bulloides Vogler; Pessagno, p. 360, Pl. 6, figs. 13, 14.

1963 ______"______ (Glotruncana) bulloides Vogler; van Hinte, pp. 83-4, Pl. 8, figs. 3, 4.

1967 ______"______ bulloides Vogler; Pessagno, pp. 324-8, Pl. 64, figs. 15-17, Pl. 67, figs. 1-3, Pl. 73, figs. 9, 10, Pl. 75, figs. 4-8.

1969 Globotruncana marginata (Reuss); Douglas, pp. 182-3, Pl. 8, fig. 5 (non fig. 4.)

1969 ______"______"______ (Reuss); Douglas & Rankin, pp. 203-7, figs. 14, 15.

1969 ______"______ pseudolinneiana (Pessagno); Douglas & Rankin, pp. 207-8, figs. 16, 17.

1970 ______"______ bulloides Vogler; Porthault, in Donze et al, p. 83, Pl. 11, figs. 20-22.

1973 ______"______"______ Vogler; Postuma, pp. 20-1, 7 figs.

Test free, low trochospire, slightly biconvex in side view, margins truncated with two distinct keels around the periphery; chambers distinct, inflated both dorsally and ventrally, petaloid, increasing uniformly in size, six to seven in final whorl; sutures distinct, depressed strongly at the margins, radial, curved, masked by lobate keel on the umbilical surface; wall coarsely perforate, calcareous, pustular ornament, moreso on spiral side, keels widely set and beaded; aperture umbilical, umbilicus small with evidence for the development of a tegilla, although this is very rarely preserved.

Max. dimensions: Diameter 0.49mm.Thickness 0.23 mm.

Remarks: This species has often been confused with G. marginata (Reuss), which stems from the fact that they are probably end members of one lineage with a full range of transitional forms between the two. The two species have been separated here using the criteria outlined by Herm (1962) and found to be of value in the present study. Globotruncana bulloides is distinguished as follows:-

a) the umbilicus is small and the aperture is umbilical,

b) the keels are well developed on the umbilical side and are distinctly lobate,

c) the keels are also widely spaced around the periphery.

These features are not seen in true examples of G. marginata, which has narrow keels, radial sutures on the umbilical side and a shallow, wide umbilicus. There is rarely evidence for the development of a tegilla in the latter species.

The present author agrees with Pessagno (1967) with regards to the inclusion of G. culveriensis Barr into the synonomy of G. bulloides, the presence of a single keel on the final chamber is quite variable and in this case is not considered to be a distinct enough character in the erection of a separate species.

There is a strong possibility that G. paraventricosa (Hofker) should be considered as conspecific with the present group, however the original diagrams are too poor to be certain of a good comparison and the description is also imprecise on important characters.

Range: Assemblage Zones A-F.

Globotruncana canaliculata (Reuss) 1854

Pl. 7, figs. 12, 13, 14, 15.

1854 Rosalina canaliculata Reuss, p. 70, Pl. 26, fig. 4a, b.

1956 Globotruncana marginata (Reuss); Jirova, Pl. 1, fig. 1a-c.

1960 " canaliculata (Reuss); Trujillo, p. 341, Pl. 50, fig. 1a-c.

1967 Marginotruncana " (Reuss); Pessagno, pp. 302-4, Pl. 74, figs. 5-8.

1970 Praeglobotruncana (Dicarinella) canaliculata (Reuss); Porthault, in Donze et al, p. 72, Pl. 13, fig. 24.

Test free, low trochospiral, relatively large diameter, margin truncate, with two distinct keels; chambers distinct, inflated on both sides, sub-globular, petaloid, 6 to 8 in the final whorl; sutures constricted, radial, straight to slightly curved on the umbilical side, curved on the spiral side; wall perforate, calcareous, well developed pustular ornament, almost tuberculate, keels distinct, beaded; aperture shallow interomarginal arch, umbilical-extraumbilical, may be covered by tegilla with distinct portici.

Max. dimensions: Diameter 0.58mm. Thickness 0.27 mm.

Remarks: Typical of the genus as a whorl, this species has often been confused with other closely similar species. In this case G. lapparenti Brotzen is often quoted, although having much less globular chambers, and a fairly wide umbilicus. G. marginata is again often confused with this species but this has distinctly fewer chambers in the final whorl. Both were described by Reuss (1854) from the same area of Austria, and in fact the specimen figured as a neotype for G. marginata (Reuss) by Jirova (1956) is thought to be G. canaliculata rather than the species it was intended to represent.

Range: Assemblage Zone A to base of Assemblage Zone E.

Globotruncana concavata (Brotzen) 1934

Pl. 8, figs. 1,2,3.

1934 Rotalia concavata Brotzen, p. 66, Pl. 3, fig. 6.

1941 ? Globotruncana linnei (d'Orbigny) subsp. pendens Vogler, p. 287, Pl. 24, figs. 4-6, not figs. 1,2,3,7.

1955 Globotruncana (Globotruncana) ventricosa ventricosa White; Dalbiez, p. 168, t. figs. 7a-d.

1955 " " ventricosa carinata Dalbiez, pp. 168-9, t. figs. 8a-c.

1957 " concavata (Brotzen); Bolli et al, p. 57, Pl. 13, fig. 3a-c.

non 1962 " " (Brotzen); Herm, pp. 70-1, Pl. 5, fig. 4.

1962 " " (Brotzen); Barr, p. 569, Pl. 71, fig. 4a-c.

1967 Marginotruncana " (Brotzen); Pessagno, pp. 304-5, Pl. 58, figs. 1-9, Pl. 95, figs. 6,7, Pl. 99, figs. 1-3.

1970 Praeglobotruncana (Dicarinella) concavata (Brotzen); Porthault, in Donze et al, p. 73, Pl. 10, fig. 7,8. Pl. 13, fig. 25.

1971 Globotruncana concavata (Brotzen); Postuma, pp. 26-7, 7 figs.

Test free, low trochospire, dorsal side flat to slightly concave, ventral side strongly convex, angular periphery with two distinct, closely set keels; chambers distinct, rapidly increasing in size in final whorl, flat on dorsal side, strongly inflated in later stages on on the umbilical side, five to six chambers in the final whorl; sutures distinct, slightly elevated and curved on the spiral side, radial and deeply constricted on the umbilical side;

wall perforate, calcareous, smooth to rugose on the dorsal side, pustular ornament developed on the outer umbilical surfaces, keels beaded; aperture interomarginal low arch, umbilical to slightly extra-umbilical, umbilicus deep, some evidence for the development of a tegilla.

Max. dimensions: Diameter 0.57 mm. Thickness 0.34 mm.

Remarks: The occurrence of this species is sporadic, but nevertheless of great stratigraphic value. It is a distinctive form and preservation has been relatively good.

Barr (1962) notes the range of G. concavata (Brotzen) as covering most of the Micraster zones of Culver Cliff. It has been found with certainty throughout the M. coranguinum Zone as far as the lowest part of the U. socialis Zone in the present study, from Kent, Essex and Quidhampton.

Van Hinte (1976) indicates the range of G. concavata as encompassing the upper half of the Coniacian and the lower part of the Santonian, a situation with which the present distribution fully equates, if the zonal scheme outlined by Casey et al (in press) is followed.

Range: ?Assemblage Zone B. Assemblage Zones D to F.

Globotruncana linneiana (d'Orbigny) 1839

Pl. 8, figs. 4,5,6.

1839 Rosalina linneiana d'Orbigny, p. 110, Pl. 5, figs. 10-12.

1918 " linnei d'Orbigny; de Lapparent pp. 1-17, t. fig. 2, fig. g.

1941 Globotruncana linnei typica (d'Orbigny); Vogler, p. 286, Pl. 23, figs. 12-22.

1941 " " tricarinata (Quereau); Vogler (part), p. 287, Pl. 23, figs. 22-5, 27, 28, 31, (non 26, 29, 30).

1956 ___"___ linneiana (d'Orbigny); Bronniman & Brown, pp. 540-2, Pl. 20, figs. 13-17, Pl. 21, figs. 16-18.

1962 Globotruncana lapparenti lapparenti Brotzen; Herm, pp. 82-4, Pl. 6, fig. 2.

1962 ___"___ tricarinata (Quereau); Herm, pp. 93-4, Pl. 6, fig. 4.

1962 ___"___ linneiana linneiana (d'Orbigny); Barr, pp. 571-2, Pl. 69, fig. 7a-c, Pl. 72, fig. 5.

1962 ___"___ " tricarinata (Quereau); Barr, pp. 573-4, Pl. 70, fig. 2a-c.

1967 ___"___ "___ (d'Orbigny); Pessagno, pp. 346-9, Pl. 72, figs. 1-4-9, Pl. 97, figs. 11-13. (full synonomy)

1969 ___"___ "___ (d'Orbigny); Douglas, pp. 181-2, Pl. 3, fig. 1a-c.

Test free, low trochospiral, both sides flat to very slightly convex, margins distinctly angular and truncated, with two well spaced keels, the wall in between these is vertical; chambers distinct, petaloid, flat or very slightly inflated, six to seven in the final whorl; sutures curved, raised on the spiral side, slightly lobate to radiate on the umbilical side, slightly constricted at the margins; wall perforate, calcareous, smooth to slightly pustulose; primary aperture intero-marginal, preservation to poor to show the development of a tegilla.
Max. dimensions: Diameter 0.70 mm. Thickness 0.25 mm.
Remarks: Problems concerning this species have arisen ever since d'Orbigny first described the species from beach sands from Cuba. Both Pessagno (1967) and Douglas (1969) give useful lengthy discissions of the species, and that of the latter is particularly valid.

In the present study G. linneiana occurs higher in the section, where it can be more easily distinguished from G. pseudolinneiana (Pessagno) by the wider spacing of its keels.

Barr's material from the Isle of Wight, housed in the British Museum (Natural History), has been examined and both his subspecies of G. linneiana have been included in the present synonymy.

Range: Assemblage Zones D to F.

Globotruncana marginata

Pl. 8. figs. 7,8, 9.

1845 Rosalina marginata Reuss, p.36, Pl.8, figs. 54a,b,74a,b, Pl.13,fig. 68a,b.

1854 " " . Reuss; Reuss, p.69, Pl.26,fig. 1a-c.

1910 Globigerina marginata (Reuss); Heron-Allen & Earland, p.424, Pl.9, figs. 1-3.

1917 " " (Reuss); Chapman, p.44, Pl.12,fig.126.

1925 " " (Reuss); Franke, p.93. Pl.8, fig.16a-c.

1928 " " (Reuss); Franke, pp.192-3,Pl.18,fig.9a-c.

1937 " " (Reuss);Loetterle,pp.44-5, Pl.7,fig.3a-c.

1946 Rosalinella " (Reuss); Schijfsma,pp.97-8,Pl.7, fig.10a-c.

1946 Globotruncana " (Reuss); Cushman, p.150, Pl.62,figs.1,2.

1954 " " (Reuss); Hagn & Zeil,pp.46-7,Pl.2, fig.4a-c, Pl.7, figs. 5,6.

1956 Marginotruncana marginata (Reuss); Hofker, pp.522-4, t. figs. 6a-f, 7, 8a-d.

1956 Marginotruncana paraventricosa Hofker, p.328, t.figs. 17-18.

1956 Globotruncana marginata (Reuss): Jirova, pp.248-9,Pl.3, fig.1a-c, (non Pl.1, figs 1-3, Pl.2; figs. 1-2, Pl.3, figs. 2,3.)

1958 ______"______"______ (Reuss); Witwicka, Pl. 17, fig. 34a-c.

1960 ______"______"______ (Reuss); Tollmann, pp. 194-5, Pl. 21, fig. 3.

1961 <u>Globotruncana paraventricosa</u> (Hofker); Vasilenko, p. 151, Pl. 33, fig. 1. Pl. 34, figs. 1-4, Pl. 35, fig. 1.

1962 ______"______ <u>marginata</u> (Reuss); Barr (part), pp. 574-5, Pl. 72, figs. 7, 8a-c.

1962 ______"______"______ (Reuss); Herm, pp. 85-6, Pl. 5, fig. 5.

1965 ______"______"______ (Reuss); van Hinte, p. 23, Pl. 1, fig. 2a-c.

1967 <u>Marginotruncana</u> ______"______ (Reuss); Pessagno, pp. 307-310, Pl. 54, figs. 10-12. 16-18, Pl. 56, figs. 10-12, Pl. 99, figs. 5-7.

1969 <u>Globotruncana</u> ______"______ (Reuss); Douglas, pp. 182-3, Pl. 8, fig. 4 (non fig. 5).

1970 <u>Marginotruncana</u> ______"______ (Reuss); Porthault, in Donze et al, pp. 74-5, Pl. 10, figs. 18-20, Pl. 13, figs. 21, 23.

1973 <u>Globotruncana</u> ______"______ (Reuss); Norling, in Bergström et al, p. 111, Pl. 8, fig. 1a-c.

Test free, low trochospire, very slightly biconvex, margin with two closely placed keels; chambers inflated both ventrally and dorsally, globular, petaloid, elongate in the direction of growth, five to six in the final whorl; sutures constricted, radial, straight on the umbilical side, straight to slightly curved dorsally; wall perforate, calcareous, smooth to finely tuberculate, keels slightly beaded; aperture umbilical interomarginal low arch, may be slightly extra-umbilical;

umbilicus wide, shallow, little evidence for the presence of a tegilla. Max. dimensions: Diameter 0.63 mm. Thickness 0.25 mm.

Remarks: Reuss's original diagrams of this species are far too small to show any of the important characters of this species, first described from the Bohemian Upper Cretaceous (1845). We are therefore dependant on his later work on the Austrian Cretaceous (1854), in which G. marginata is figured on a much larger scale. In this diagram the characteristic features of the narrow keels, radial straight sutures and arcuate inflated chambers are all distinct, and it is this concept of the species which has been followed in the present study.

Hofker (1956) uses what he believes to be Rosalina marginata Reuss as type species for his new genus Marginotruncana, although his choice of single keeled forms for this species leads one to doubt his identification of the group. He also placed the single keeled Praeglobotruncana turbinata (Reichel) in his new genus, and this, in a genus defined on a species which was originally described with two keels, makes his taxonomic designations totally unacceptable.

In the same year Jirova (1956) attempted to define a neotype of G. marginata, the original specimens being lost. However, the range of variation included within her descriptions goes well beyond that illustrated by Reuss and the specimen selected as the neotype bears a much closer resemblence to G. canaliculata (Reuss), first described from the same section as G. marginata.

Pessagno's (1967) concept of the species is accepted, although his use of the generic name Marginotruncana Hofker is again questioned due to the dubious nature of the original description.

Globotruncana pseudolinneiana (Pessagno) 1967

Pl. 8, figs. 14, 15, 16.

1966 Globotruncana linneiana (d'Orbigny); Caron, p. 83, Pl. 5, fig. 3a-c.

1967 Marginotruncana pseudolinneiana Pessagno, p. 310, Pl. 65, figs. 24-27, Pl. 76. figs. 1-3.

1970 " " Pessagno; Porthault, in Donze et al, p. 79, Pl. 11, figs. 9, 10, Pl. 13, figs. 19, 22.

Test free, very low trochospiral, both sides flat to slightly convex, two narrowly spaced, beaded keels around the whole periphery; chambers elongate petaloid on spiral side, lobate on umbilical side, flat, five to seven in the final whorl, increasing regularly in size; sutures slightly depressed at the margins, raised both dorsally and ventrally curved on spiral side, lobate on umbilical side; wall coarsely perforate, calcareous, keels show distinct rugose beading; aperture extra-umbilical to umbilical, low interomarginal arch; umbilicus shallow, wide, no evidence for the presence of a tegilla has been found, although the umbilical area is rarely preserved well.

Max. dimensions: Diameter 0.68 mm. Thickness 0.19 mm.

Remarks: As Porthault (1970) comments, there appears to be a continuous range in morphology between the present species and G. linneiana (d'Orbigny), with all transitional forms present between the two. The characters which are considered to be important in this lineage are the migration of the aperture into a totally umbilical position and the relative depth of the chambers, which tends to increase with time. Porthault asserts that G. linneiana does not truly appear until late in the Santonian, whereas it is here considered that earlier forms may be placed in this species, extending its' range into the lower Santonian.

This species is common throughout most of the section, but more particularly in the lowermost Assemblage Zones A and B.

Range: Assemblage Zones A-F.

Globotruncana renzi (Gandolfi) 1942

Pl. 8, figs. 17,18,Pl. 9, fig. 2.

1936 Globotruncana appenninica-linnei Renz, Pl. 6, figs. 16,21-6, (non figs. 17-20), Pl. 8, figs. 3,5 (non fig. 2).

1942 " renzi Thalmann, p. 8. (nomen nudum).

1942 " " Gandolfi, p. 124, t. fig. 45a-c, Pl. 4, fig. 15. (non Pl. 3, fig. 1a-c, Pl. 4, figs. 16,28-9, Pl. 10, fig. 2).

1966 " " Gandolfi; Caron, pp. 77-9, fig. 4. (non fig. 5.)

1967 Marginotruncana " (Gandolfi); Pessagno, pp. 310-3, Pl. 55, figs. 4-7, Pl. 65, figs. 20-3, Pl. 98, figs. 3,4.

1970 " " (Gandoli); Porthault, in Donze et al, pp. 75-6, Pl. 10, figs. 13,14.

1971 Globotruncana " Gandolfi; Postuma, pp. 54-5, 7 figs.

Test free, low trochospire, plano-convex to biconvex, periphery acutely angled, marked by two very narrowly spaced keels, normally fusing to form a single keel in the later chambers; chambers elongate petaloid, inflated on the umbilical side, five to six in the final whorl, increasing gradually in size; sutures radial and slightly constricted on umbilical side, raised as curved beaded keel on spiral side; wall perforate, calcareous, smooth; aperture extra-umbilical to umbilical, poorly preserved in present examples.

Max. dimensions: Diameter 0.56 mm. Thickness 0.25 mm.

Remarks: Like G. concavata (Brotzen) the present species shows a sporadic occurence in the English succession, although its range is slightly lower in the section.

Porthault (1970) and van Hinte (1976) both record it as having an Upper Turonian to middle Coniacian distrubution, and if Casey et al (in press) are followed, this stratigraphic range is also present in the English Chalk.

Range: Assemblage Zone A to the base of Assemblage Zone D.

Genus WHITEINELLA Pessagno 1967

Genotype Whiteinella archaeocretacea Pessagno 1967

Whiteinella baltica Douglas & Rankin 1969

Pl. 10, fig. 5. 1,2,3,4.

1969 Whiteinella baltica Douglas & Rankin, p. 197, fig. 9A-I.

1969 Hedbergella bornholmensis Douglas & Rankin, p. 193, fig. 6A-I.

Test free, low trochospiral, periphery strongly lobate and rounded; chambers distinctly inflated, particularly in final whorl of four to five chambers, more usually four, sub-sphaerical; sutures constricted, radial to slightly curved; wall calcareous, perforate with a tuberculate ornament; aperture umbilical to slightly extra-umbilical, with evidence of an umbilical flap in well preserved specimens.

Max. dimensions: Diameter 0.37 mm. Thickness 0.24 mm.

Remarks: This species, originally described from southern Scandinavia, has proved to be relatively common in the English succession. The chamber arrangement and umbilical position of the primary aperture is quite distinctive. Topotypic material from the island of Bornholm has been extensively studied and it is thought that Hedbergella bornholmensis should probably be included in the synonomy of W. baltica, the differences outlined by Douglas & Rankin being merely representative of the stage of growth. A study of the population shows a full range between the two species.

Range: Assemblage Zones A to E.

Genus ARCHAEOGLOBIGERINA Pessagno 1967

Genotype Archaeoglobigerina blowi Pessagno 1967

Archaeoglobigerina bosquensis Pessagno 1967

Pl. 10, figs. 5,6.

1967	Archaeoglobigerina bosquensis	Pessagno, pp. 316-7, Pl. 60, figs. 7-12.
1969	" "	Pessagno; Douglas & Rankin, pp. 199-200. figs. 10,11.

Test free, medium to high trochospiral, periphery lobate chambers distinctly inflated, globular, increasing in size, final chamber may be small and becoming positioned over the umbilicus, five to six in the final whorl; sutures radial, straight, deeply constricted; wall perforate, calcareous, rugose in early chambers of last whorl; aperture umbilical interomarginal semi-circular arch, covered by a small flap, which is rarely preserved, umbilicus deep and narrow.

Max. dimensions: Diameter 0.44 mm. Thickness 0.28 mm.

Remarks: As Douglas & Rankin (1969) point out, the juvenile forms of this species are difficult to distinguish from the W. baltica group, although more adult forms tend to be larger, with a higher trochospire and a larger number of chambers in the final whorl.

It appears slightly later in the English succession than W.baltica and it is thought that it could well be a continuation of the same evolutionary lineage.

Range: Upper part of Assemblage Zone C to Assemblage Zone F.

DISCUSSION OF THE FAMILIES ROTALIPORIDAE SIGAL & GLOBOTRUNCANIDAE BROTZEN.

When viewed from a chronological standpoint it appears that the division of the Rotaliporidae and the Globotruncanidae, as discussed by Loeblich & Tappan (1964) is one of a stratigraphic nature rather than being phylogenetically based. This classification has been used in the present study quite successfully, although it is felt that a few comments should be made with regards to a few of the taxa which may be positioned incorrectly.

The use of the family name Rotaliporidae is questioned, when it is based on a genus which is an off-shoot of the main Hedbergella stock. Surely the Rotalipora group should have a lower taxonomic status than the ancestral, and longer ranging Hedbergella. Banner & Blow (1959), in their discussion of the Globigerinacea, would seem to indicate a similar view, as they illustrate (t. fig. 2) the Rotalipora and Globotruncana genera evolving separately from a common Hedbergella stock.

There is the possibility that the Globotruncanidae originated from the Rotaliporidae via the Praeglobotruncana group, a concept followed by the present author.

Pessagno (1967) attempted to bridge a further transitional stage by introducing the Marginotruncanidae as the intermediate form between the other two families. However, as mentioned previously, the use of this name by Pessagno, based on an incorrectly identified group of specimens of Hofker's (1956), cannot here be supported.

It is acknowledged however, that there is a substantial group of primitive members of the genus _Globotruncana_ present during the late Turonian - Coniacian interval, characterised by a more extra-umbilical position of the primary aperture, and the lack of umbilical ornamentation in the form of a tegilla. This group, including species such as _G. pseudolinneiana_, _G. renzi_, _G. canaliculata_ and particularly _G. marginata_, has been encountered in large numbers in the course of this work and the relationships of these species with their later relatives has been discussed. There is a need to recognise this primitive group, as noted by Porthault (1970, 1974), but the use of the name Marginotruncanidae, is seriously questioned.

Porthault also appears to be correct in his grouping of the genera _Whiteinella_, _Archaeoglobigerina_ and _Rugoglobigerina_ under one taxonomic heading, rather than the bilateral division of _Whiteinella_ into the Marginotruncanidae and the other two into the Globotruncanidae, as suggested by Pessagno (1967). These three genera are believed to be one evolutionary lineage, originating from the _Hedbergella_ group during the mid - Turonian, represented by _Whiteinella_ in the lower Senonian, with _Archaeoglobigerina_ and _Rugoglobigerina_ arising from this basic stock.

Thus there are several major planktonic lineages present in the lower Senonian, running their own separate parallel courses. The unkeeled forms of the genus Hedbergella continue as they have done since the Lower Cretaceous, although with decreased importance. From this evolves the Whiteinella - Rugoglobigerina lineage discussed above, which continues through the Maastrichtian.

There is an abundance of "primitive" double - keeled species during the Turonian and early Coniacian, including G. renzi, G. pseudolinneiana and G. canaliculata. The evolutionary trend towards more lobate umbilical sutures and wider keels, occurs during the Coniacian, typified by the abundance of transitional variants between G. marginata and G. bulloides. By the mid - Santonian the distinct G. linneiana plexus and the other Late Senonian lineages have evolved.

A brief summary of the family Globotruncanidae, as encountered in the present work, is given in Figure 4:5, and as a classification should be correctly based on phylogenetic relationships rather than stratigraphic divisions, it is suggested that lineages such as those illustrated should be used as the basis of new taxonomic groupings.

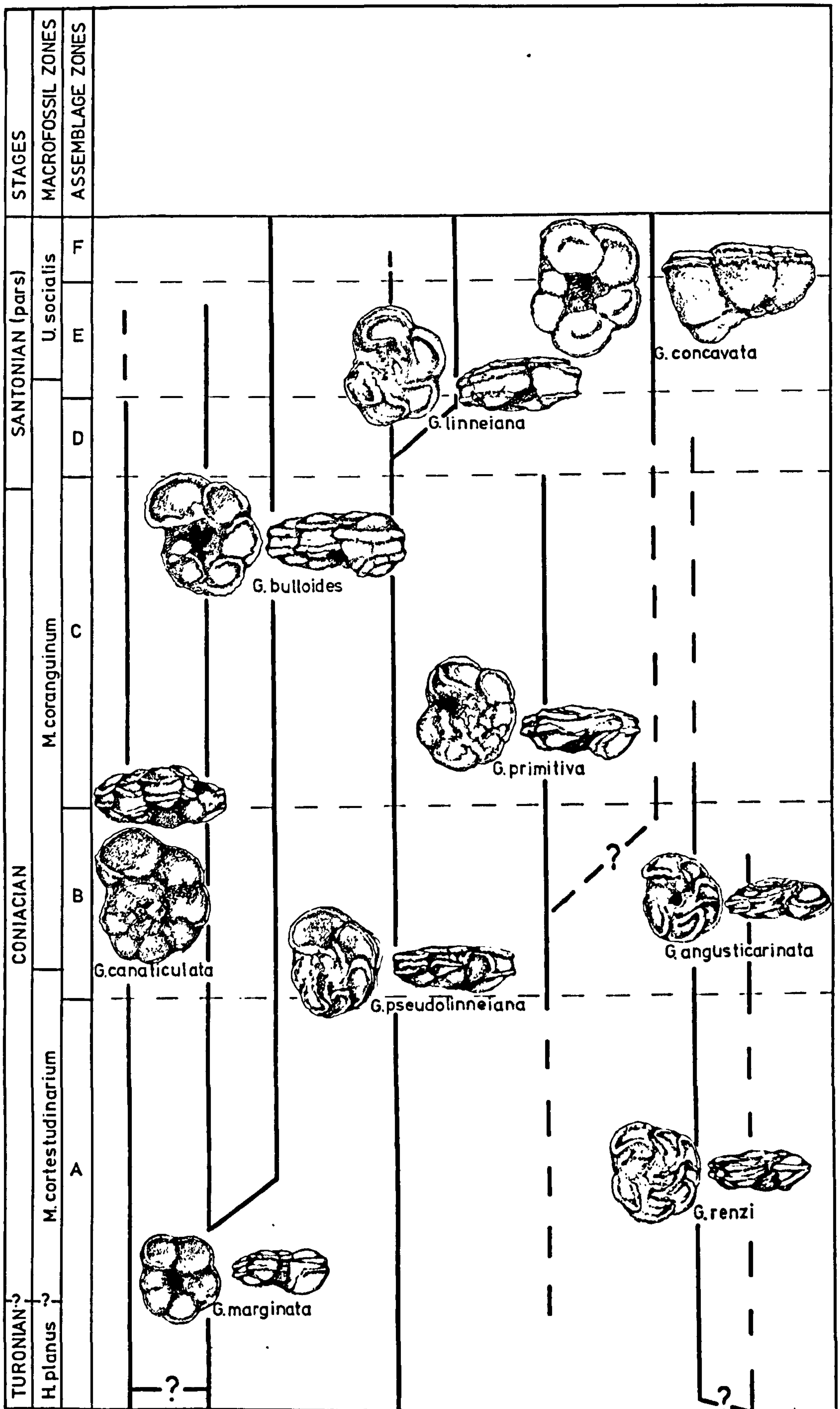


Fig. 4:5 Lower Senonian evolutionary trends in the genus Globotruncana

Superfamily ORBITOIDACEA Schwager 1876

Family EPONIDIDAE Hofker 1951

Genus EPONIDES De Monfort 1808

Genotype Nautilus repandus Fichtel & Moll 1798

Eponides cf. concinna Brotzen 1936

Pl. 10, figs. 7, 8.

1936 Eponides concinna Brotzen, p. 167, Pl. 12, fig. 4a-c.

1966 " cf. concinna Brotzen; Barr, p. 505, Pl. 79, fig. 2a-c.

Test free, trochoid, biconvex, dorsal side more weakly convex than ventral, partially involute, tightly coiled, periphery almost circular, more rarely slightly lobate, chambers distinct, slightly inflated, moreso on the ventral side, gradually increasing in size, 9 to 11 in the final whorl, which tends to overlap and hide earlier chambers; sutures distinct, dorsally flush, oblique, ventrally slightly depressed, radiate, curved; wall smooth, calcareous, finely perforate; aperture narrow slit, along the inner margin of the final chamber, extending from the umbilicus almost to the peripheral edge; umbilicus varies from shallow to more normally being totally filled by an umbilical boss, which may be apparent on the dorsal side.

Max. dimensions: Diameter 0.42 mm. Thickness 0.20 mm.

Remarks: The variable characteristic of this species appears to be the presence and form of the central boss, or plug, as it is referred to by Barr (1966). Brotzen (1936) refers to this variation in his original description, although the typical form in his study appears to be that which has a central boss visible on the dorsal side, and a shallow umbilicus on the ventral. The present form differs, as described above, in having a distinct central boss present on the umbilical side.

Examples of Barrs' material, which were extracted from the isolated pocket of Senonian chalk of Ballydeenlea, Southern Ireland, are housed in the British Museum (Natural History) (No. P45697). These have been examined and his specimens have proved to be identical to those noted from sections across southern England.

Range: Top of Assemblage Zone D - Assemblage Zone F.

Family CIBICIDIDAE Cushman 1927

Subfamily CIBICIDINAE Cushman 1927

Genus CIBICIDES De Monfort 1808

Genotype Cibicides refulgens De Monfort 1808

Cibicides beaumontianus (d'Orbigny) 1840

Pl. 10, figs. 9,10,11.

1840	Truncatulina beaumontiana	d'Orbigny, p.35, Pl.3, figs.17-19.
1878	" lobatula	(d'Orbigny); Marsson, p.167, Pl.5, fig. 38a-f.
1899	" convexa	Reuss; Egger, p.149, Pl.18, figs.25-7.
1928	" beaumontiana	d'Orbigny; Franke, pp.176-7, Pl.XVI, fig. 6a-c.
1934	Cibicides "	(d'Orbigny); Brotzen, p.61.
1936	" excavata	Brotzen, pp.189-190, Pl.13, figs. 7a-c, 8a-c.
1941	" beaumontiana	(d'Orbigny); Marie, pp.249-250, Pl.37, figs.352-4.
1946	" excavata	Brotzen; Schijfsma, pp.100-1, Pl.6, fig. 7a-c.
1948	" "	Brotzen; Williams-Mitchell, p.103, Pl.9, fig.6a,b.

1954 ______ " (Cibicides) excavatus excavatus Brotzen; Vasilenko, pp. 131-2, Pl. 20, figs. 1a-c, 2a-c.

1957 ______ " excavata Brotzen; Hofker, pp. 93-4, t. fig. 96a-i.

1957 ______ " beaumontianus (d'Orbigny); McGugan, p. 344, Pl. 32, fig. 24a-c.

1961 ______ " (Cibicides) excavata Brotzen; Vasilenko, p. 132, Pl. 26, fig. 3a-c.

1966 ______ " beaumontiana (d'Orbigny); Barr, pp. 507-8, Pl. 79, fig. 4a-c.

Test attached, plano-convex, shape variable, dorsal side may become concave, ventral side distinctly inflated, convex, margins distinctly rounded; chambers distinct, inflated, sub-globular, increasing rapidly in size, five to six in the final whorl, may become elongate along the direction of growth in later stages; sutures distinct, depressed, straight, radially arranged; wall smooth, to very slightly rugose on the ventral side, due to it's coarsely perforate nature, less distinctly perforate on the dorsal side, calcareous, relatively robust; aperture equatorial slit to semi-circular hole, extending back along the dorsal side, following the spiral suture.

Max. dimensions: Diameter 0.68 mm. Thickness 0.46 mm.

Remarks: The attached habit of this species leads to considerable morphological variation, especially on the dorsal side, along which the attachment is made. Due to this variation it follows that there has been a subsequent divergence of nomenclature.

The original figuresgiven by d'Orbigny (1840), allowing for their stylised form, do illustrate the typical form of the species. It should also be noted that examples of this species examined by d'Orbigny were also derived from material taken from southern England. Brotzen (1936) erected the species C. excavata for examples taken from Eriksdal, and attempted to distinguish this from C. beaumontianus (d'Orbigny). The characters he chose for the separation of C. excavata were the strongly rounded nature of the margins, the distinct appearance of the chambers on the ventral side, and the presence of an umbilicus. All of these are believed to fall within the range of variation exhibited by C. beaumontianus, thus the two forms are thought to be synonymous.

The stratigraphic value of this species and closely related forms of southern England was first noted by Williams-Mitchell (1948), and this is discussed more fully below.

Range: Assemblage Zones D - F.

Cibicides beaumontianus (d'Orbigny) var. A.

Pl. 10, figs. 12,13.

1954 Cibicides (Cibicides) excavatus excavatus Brotzen; Vasilenko, pp. 131-2, Pl. 20, fig. 3a,b.

1961 " " " Brotzen; Vasilenko, p. 132, Pl. 26, figs. 1a,b, 2a,b.

Test attached, dorsal side strongly concave, forming straight groove, ventral side convex, inflated, margins acute; chambers slightly inflated, increasing uniformly in size; wall calcareous, perforate on ventral side; aperture marginal, semi-circular arch.

Max. dimensions: Diameter 0.59 mm. Measured along the long axis.
Thickness 0.28 mm.

Remarks: The basic morphology is that seen in the typical forms of Cibicides beaumontianus (d'Orbigny) except for one major feature. The form of attachment is such that the dorsal side becomes extremely concave, to the extent that it is almost enrolled. All that remains visible of this enrolled side is an incomplete tube-like depression, through which a piece of plant matter may have passed during life.

This distinct variant has been noted from the U.S.S.R. in general by Vasilenko (1954) and more particularly from the Mangyshlak Peninsula, on the eastern seaboard of the Caspian, by the same author (1961).

It may simply be an extreme variant of C. beaumontianus, but as its stratigraphic distribution is of some value, it has been maintained as a separate variety.

Range: Assemblage Zones E - F.

Cibicides ribbingi Brotzen 1936

Pl. 11, figs. 1,2,3.

1936	Cibicides ribbingi	Brotzen, pp. 186-9, Pl. 13, figs. 5a-c, 6a-c, t. figs. 67, 68.
1948	" "	Brotzen; Williams-Mitchell, p. 103, Pl. 9, fig. 5a,b.
1973	" "	Brotzen; Koch, pp. 211-2.

Test attached, plano-convex, dorsal side distinctly flattened, ventral side inflated slightly, convex, peripheral outline extremely variable, especially in later chambers which show a tendency to become irregular, margin acutely angled; chambers distinct, increasing gradually in size; sutures flush on the dorsal side, slightly depressed on the ventral side, straight, radiate; wall calcareous, smooth, perforate particularly, on the ventral surface; apertural slit on the inner margin of the final chamber, extending round towards the umbilicus, which may be shallow to absent, and on to the dorsal surface.

Max. dimensions: Diameter 0.57 mm. Thickness 0.25 mm.

Remarks: There is the possibility that this species could be a phenotypic variant of C. beaumontianus (d'Orbigny), and this was suggested by Barr (1966), when he included C. ribbingi Brotzen in the synonomy of d'Orbigny's species. This is not thought to be the true situation for the following reasons. The differences in overall shape between the two species are distinct and there is no evidence of any transitional forms, although it is felt that the species in question are very closely related. Furthermore, the lowest occurence of C. ribbingi is always slightly later than that of C. beaumontianus, and this fact is of stratigraphic value.

The first appearance of this species was also noted by Williams-Mitchell (1948), and his figured specimens have been examined in the British Museum (Natural History) (No. P. 50312). These were found to be identical to be identical to the forms discussed here.

Range: Assemblage Zones E -F.

The Stratigraphic value of the Cibicides beaumontianus-C.ribbingi Group.

As noted above, the significance of this group in the stratigraphical succession was first recorded by Williams-Mitchell (1948), in his discussion of the zonal value of Foraminifera in the English Chalk.

The distribution that he records for the two species C. ribbingi Brotzen and C. excavata Brotzen, here referred to as C. beaumontianus (d'Orbigny), has proved to be perfectly correct, even down to the slightly later appearance of C. ribbingi, a few metres above C. beaumontianus.

D'Orbigny's species is the first to be found in the southern England succession, appearing a few metres below the basal boundary of Assemblage Zone E in the present zonation. Cibicides ribbingi follows shortly afterwards, and its appearance is a useful indication of the level at which the assemblage zone boundary should be drawn.

Finally, and normally within two to three metres of the appearance of C. ribbingi, C. beaumontianus var. A. occurs completing the distinct sequence which arises across the zonal boundary. This order of appearance has been found on several occasions in the course of the present study.

The ranges of these species, as recorded above, do not entirely correlate with those recorded on the Continent. For example, Robaszynski (per.comm). has indicated that C. ribbingi appears lower in the sections seen in northern France, and therefore any value placed on the ranges of these species must be considered purely on a regional basis.

Cibicides sp. A.

Pl. 11, figs, 4,5.

Test small, plano-convex, dorsal side flat, ventral side strongly dome-shaped, circular in outline, margins sharply angular; chambers distinct, uninflated, gradually increasing in size, 9 to 11 in the final whorl, which overlaps and covers the earlier stages;

sutures flush with the surface, distinct, radially arranged, curved backwards on both sides; wall calcareous, smooth, finely perforate; aperture narrow slit which extends over the margin onto the dorsal side, and down the inner margin of the final chamber on the ventral side, towards the umbilicus; central calcareous boss, visible on both sides, flush with the surface of the test.

Max. dimensions: Diameter 0.22 mm. Thickness 0.12 mm.

Remarks: A consistant member of the fine sieve fraction throughout the Coniacian succession in this country, and as far as is known, previously unrecorded. It is similar to Cibicides blanpiedi Toulmin (1941), but as this species is known only from the lower part of the Eocene any relationship is extremely unlikely.

Range: Assemblage Zones B - F.

Superfamily CASSIDULINACEA d'Orbigny 1839

Family PLEUROSTOMELLIDAE Reuss 1860

Subfamily PLEUROSTOMELLINAE Reuss 1860

Genus PLEUROSTOMELLA Reuss 1860

Genotype Dentalina subnodosa Reuss 1860

Pleurostomella subnodosa Reuss 1860

Pl. 11, figs. 6, 7.

1860	Pleurostomella subnodosus	Reuss, p. 60, Pl. VIII, fig. 2.
1878	" "	Reuss; Marsson, p. 133.
1891	" "	Reuss; Beissel, p. 64, Pl. XII, figs. 30-38.
1899	" "	Reuss; Egger, p. 48, Pl. XVI, figs. 27, 28.
1925	" "	Reuss; Franke, p. 22, Pl. II, fig. 11.
1928	" "	Reuss; Franke, p. 129, Pl. XI, fig. 28a, b.

1936	Nodosarella articulata	Brotzen, pp. 139-140, Pl. 9, fig. 10a-c, t. fig. 49.
1946	Pleurostomella subnodosus	Reuss; Cushman, p. 132, Pl. 55, figs. 1-9.
1957	" "	Reuss; McGugan, p. 341.
1963	Pleurostomellina sp.	Graham & Church, p. 68, Pl. 8, fig. 12.
1964	Pleurostomella subnodosus	Reuss; Loeblich & Tappan, pp. C725, 726, fig. 594. 1a,b.
1968	" "	Reuss; Sliter, p. 110, Pl. 19, fig. 10.

Test free, elongate, cuneate, becoming more uniserial in later stages; chambers slightly inflated, initially small becoming more elongate later; sutures initially indistinct, becoming depressed, sub-horizontal to oblique; wall calcareous, perforate, smooth; aperture sub-terminal, ovoid, set in a shallow depression, upper edge slightly overhanging, lower edge showing slight development of two small teeth, internal tube present.

Max. dimensions: Length 1.36 mm. Width 0.18 mm.

Remarks: Recorded here through the upper part of the Coniacian and into the Santonian, giving this species a somewhat longer range than the Campanian distribution noted by Sliter (1968).

Range: Assemblage Zone A to the base of Assemblage Zone F.

Genus ELLIPSOIDELLA Heron-Allen & Earland 1910.

Genotype Ellipsoidella pleurostomelloides Heron-Allen & Earland 1910.

Ellipsoidella pleurostomelloides Heron-Allen & Earland 1910. Pl. 11, figs. 8,9.

1910	Ellipsoidella pleurostomelloides	Heron-Allen & Earland, pp. 413, 415, Pl. 10, figs. 1-11, figs. 1,2.

1936 Nodosarella solida Brotzen, pp. 140-1, Pl. 9, fig. 11a, b.

1964 Ellipsoidella pleurostomelloides Heron-Allen & Earland; Loeblich & Tappan, p. C728, fig. 594, 6, 7.

Test elongate, initially cuneate later becoming uniserial; chambers slightly inflated, distinct, becoming elongate; sutures slightly depressed, sub-horizontal to oblique; wall smooth, calcareous, perforate; aperture sub-terminal, transverse slit, with a slightly overhanging lip on the upper edge, internal tube present.

Max. dimensions: Length 0.79 mm. Width 0.21 mm.

Remarks: Superficially this species is extremely similar to P. subnodosus Reuss, but it is distinguished by its possession of a slit-like aperture, which is crescentic, as opposed to the large ovoid opening present in Reuss' species. It was this character alone which Heron-Allen & Earland used in the erection of this species, and they derived the trivial name from the marked resemblance to members of the Pleurostomella group.

Nodosarella solida Brotzen has been included in the present synonomy as it is considered to be identical to the lectotype (P. 41662) and paralectotypes (P. 41663 & P. 41664) of Heron-Allen & Earland, examined in the British Museum (Natural History). There are also two American forms which are noted as having a similar appearance as E. pleurostomelloides, these being E. austiniana (Cushman) and E. gracillima (Cushman), both of which have a similar distribution to the European species.

Range: Assemblage Zones D-E.

Family CAUCASINIDAE Bykova 1959

Subfamily FURSENKOININAE Loeblich & Tappan 1961

Genus CASSIDELLA Hofker 1951

Genotype Virgulina tegulata Reuss 1846

Cassidella sp. A.

Pl. 11, fig. 10.

Test free, elongate, biserial throughout, margins rounded, sides sub-parrallel, tapering slightly to the initial end; chambers distinct, elongate, low; sutures distinct, slightly depressed, curved obliquely; wall calcareous, finely perforate, smooth; aperture long narrow loop-shaped slit, extending from a terminal position down to the inner margin of the final chamber.

Max. dimensions: Length 0.63 mm. Width 0.16 mm.

Remarks: Only encountered in the uppermost part of the section at Culver Cliff, Isle of Wight, and is therefore believed to appear in the lower part of the U. socialis Zone of this country.

Range: Assemblage Zone F.

Family LOXOSTOMIDAE Loeblich & Tappan 1962

Genus LOXOSTOMUM Ehrenberg 1854

Genotype Loxostomum subrostratum Cushman 1927

Loxostomum eleyi (Cushman) 1927

Pl. 11, figs. 11, 12.

1859 Textularia obsoleta Reuss; Eley, p. 202, Pl. VIII, fig. 11, p. 195, Pl. II, fig. 11.

1878 Bolivina linearis Marsson, p. 155, Pl. III, fig. 22.

1927 Bolivinita eleyi Cushman, p. 91, Pl. 91, fig. 11.

1928	Bolivina linearis	Marsson; Franke, p. 152, Pl. XIV, fig. 1.
1931	Bolivinita eleyi	Cushman; Cushman, p. 39, Pl. V, fig. 8a, b.
1936	" "	Cushman; Brotzen, pp. 122-3, Pl. 9, fig. 5a, b. t. fig. 41.
1937	" "	Cushman; Marie, p. 264.
1941	Bolivinitella eleyi	forma typica (Cushman); Marie, pp. 190-1, Pl. 29, fig. 282a-c.
1941	" "	(Cushman) var. polygonalis Marie, p. 191, Pl. 29 fig. 283a-c.
1946	Bolivinita "	Cushman; Cushman, p. 114, Pl. 48, figs. 18-20.
1946	Bolivinitella "	(Cushman); Schijfsma, pp. 72-3, Pl. 6, fig. 10.
1948	Bolivinita "	Cushman; Williams-Mitchell, p. 103, Pl. 9, fig. 1.
1953	" "	Cushman; Hagn, pp. 76, 103, Pl. 6, fig. 24.
1957	Bolivinitella "	(Cushman); Montanaro-Gallitelli, p. 150, Pl. 34, figs. 14-17.
1957	" "	(Cushman); McGugan, p. 340.
1963	" "	(Cushman); Graham & Church, p. 51, Pl. 5, fig. 25.
1964	Loxostomum "	(Cushman); Loeblich & Tappan, p. C736, fig. 603, 2-5.
1968	" "	(Cushman); Sliter, p. 112, Pl. 20, fig. 2.
1970	Bolivinitella "	(Cushman); Porthault, in Donze et al, pp. 56-7, Pl. 8, fig. 24.

Test free, elongate, compressed, biserial, edge truncated, subangular; chambers flat, overlapping, slightly reniform in outline; sutures distinct, flush to slightly raised, curved; wall calcareous smooth, finely perforate; aperture terminal, ovoid slit, surrounded by a slightly raised lip.

Max. dimensions: Length 0.51 mm. Width 0.24 mm.

Remarks: The precise distribution of this species is difficult to assess, as it has been recorded from the Coniacian to the Campanian, over a world-wide geographical spread. However, its first appearance in the British succession, towards the base of Assemblage Zone C is extremely constant, and subsequently very useful for correlation both over short distances and on a wider regional scale.

Williams-Mitchell (1948) noted the value of this species in the English Chalk, as did McGugan (1957) in his examination of the Chalk of Northern Ireland, although the latter did not record L. eleyi from the Micraster zones.

Range: Assemblage Zones, C - F.

Family NONIONIDAE Schultze 1854

Subfamily CHILOSTOMELLINAE Brady 1881

Genus QUADRIMORPHINA Finlay 1939

Genotype Valvulina allomorphinoides Reuss 1860

Quadrimorphina allomorphinoides (Reuss) 1860

Pl. 11, figs. 13,14.

1860 Valvulina allomorphinoides Reuss, p.223, Pl. XI. fig. 6a-c.

1925 Discorbina " (Reuss); Franke, p. 91, Pl. VIII, fig. 11a,b.

1926 Discorbis " (Reuss); Cushman, p. 606, Pl. 20, figs. 18,19, Pl. 21, fig. 26.

1928 Discorbina " (Reuss); Franke, p. 189, Pl. XVIII, fig. 7a,b.

1931 Valvulineria " (Reuss); Cushman, p. 43, Pl. 6, fig. 2a-c.

1936 ______"______"______ (Reuss); Brotzen, p. 153, Pl. 11, fig. 1a-c, t. fig. 56.

1939 Quadrimorphina allomorphinoides (Reuss); Finlay, p. 325.

1941 Valvulineria " (Reuss); Cushman & Hedberg, p. 96, Pl. 23, fig. 9a-c.

1946 ______"______"______ (Reuss); Cushman, p. 138, Pl. 57, fig. 6, (non fig. 7.).

1964 Quadrimorphina " (Reuss); Loeblich & Tappan, p. C744, fig. 611, 6a-c.

1968 ______"______"______ (Reuss); Sliter, p. 114, Pl. 20. fig. 7.

Test free, biconvex, trochospiral, partially evolute, notably on spiral side, earlier whorls not visible on the more involute umbilical side, margins rounded; chambers inflated, particularly in final whorl, final chamber almost half the maximum diameter, four in final whorl; sutures distinct, flush with surface, straight, radial; wall, smooth, calcareous, finely perforate; aperture towards centre of the ventral surface, broad slit along the inner margin of the final chamber, covered by an extended flap.

Max. dimensions: Diameter 0.46 mm. Thickness 0.24 mm.

Remarks: This distinctive species is present throughout the succession, and it appears to be long ranging throughout the Senonian. Hart (1970) recorded Q. cf. allomorphinoides from the Cenomanian of south-west England.

Quadrimorphina trochoides (Reuss) 1845

Pl. 11, figs. 15, 16.

1845 Globigerina trochoides Reuss, pp. 36-7, Pl. XII, fig. 22a, b.

1925 Allomorphina cretacea Reuss; Franke, p. 28, Pl. II, fig. 26.

1928 ______"______ trigona Reuss; Franke, p. 139, Pl. XII, fig. 20.

1941 ______"______ trochoides (Reuss); Marie, p. 230, Pl. XXXV, fig. 331a–f.

Test free, trospiral, early chambers visible beneath the much more inflated final whorl, margin rounded; chambers slightly compressed, distinct, later chambers inflated, final chamber half the diameter of the final whorl; sutures distinct, flush with surface to slightly depressed, straight; wall perforate, calcareous, smooth surface; aperture long, narrow slit, along the inner ventral margin of the final chamber, overlapping by a raised lip on the upper edge.

Max. dimensions: Width of apertural face 0.35 mm.
Height of spire 0.28 mm.

Remarks: This species is not common, but its' distinctive appearance in Assemblage Zone F is of some stratigraphic value.

Most of the references to Q. trochoides have placed it in the genus Allomorphina, but Loeblich and Tappan (1954) revised the two genera on the following basis:–

> "As here restricted, Allomorphina includes involutely coiled species and Quadrimorphina trochospiral species with early coil visible at one side of the test".

They also consider the number of chambers in the final whorl to be of specific value only, and Reuss' species must therefore be placed in the genus Quadrimorphina.

Range: Assemblage Zones E – F.

Family OSANGULARIIDAE Loeblich & Tappan 1964

Genus OSANGULARIA Brotzen 1940

Genotype Osangularia lens Brotzen 1940

Osangularia whitei var. whitei (Brotzen) 1936

Pl. 12, figs. 1,2,3.

1936 Eponides whitei Brotzen, pp. 167-9, Pl. 12, figs. 6-8.

1961 Parrella " var whitei Brotzen; Vasilenko p. 91, Pl. XIV, fig. 5.

Test free, trochospiral, biconvex, equally high both on the dorsal and ventral sides, biumbonate, margin acutely angled, becoming carinate; chambers distinct, increasing gradually in size, sub-triangular in shape, seven to eight in the final whorl; sutures straight to slightly oblique, flush with the surface, radial wall calcareous, smooth; aperture narrow oblique slit towards the inner margin of the final chamber, may be surrounded by a very slightly raised lip.

Max. dimensions: Diameter 0.52 mm. Thickness 0.23 mm.

Remarks: This species is very similar to Osangularia cordieriana (d'Orbigny) and it is thought that the two are very closely related. However, O. whitei var. whitei is distinguished by a periphery which is horizontal, if viewed from the side, whereas that of O. cordieriana appears to be almost sigmoidal, it is also slightly indented at the points of intersection with the septa, a feature totally absent in the present species.

Vasilenko (1961) has figured a full range of evolutionary variations of this species ranging through the Upper Cretaceous, although within the limited vertical scope of this study only the early, ancestral forms are encountered..

Range: Assemblage Zones B – F.

Osangularia whitei var. praeceps (Brotzen) 1936

Fig. 4:6.

1936 Eponides whitei var. praeceps Brotzen, p. 169, Pl. 12, fig. 5.

1961 Parrella " var. " (Brotzen); Vasilenko, p. 92, Pl. XIV, figs. 6-8.

Test free, trochospiral, almost plano-convex, the ventral side being much flatter than the dorsal side; biumbonate, highly raised on dorsal side, àcute margin; sutures straight, radial, flush with surface; wall smooth, calcareous; aperture narrow interomarginal slit on ventral side.

Max. dimensions: Dimeter 0.44 mm. Thickness 0.25 mm.

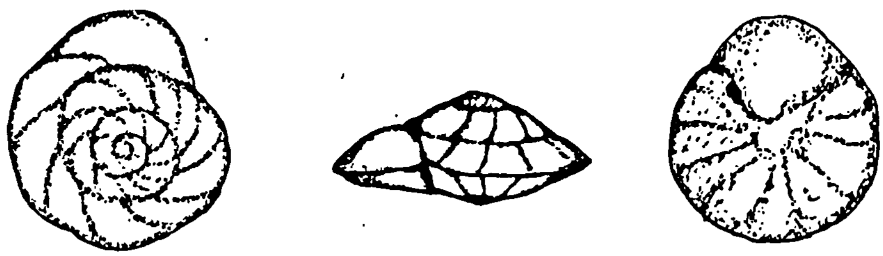
Remarks: The use of this variety is tentative, as Brotzen (1936) simply refers to the greater height of the spiral side, when compared with O. whitei var. whitei. It is believed that the rare examples encountered here fit reasonably well within the bounds of his description. As can be seen by the maximum dimensions recorded for both varieties, O. whitei var. praeceps has a relatively higher spiral surface, when it is noted that the umbilical side is almost flat.

The stratigraphic distributions recorded for both varieties are of some significance, as O. whitei var. whitei appears towards the base of Assemblage Zone B, whereas O. whitei var. praeceps. does not appear in the succession until much later in Assemblage Zone E. These ranges equate well with those illustrated by Vasilenko (1961), for the same varieties, found in sections on the eastern coast of the Caspian Sea.

Range: Assemblage Zone E.

Fig.4:6

Osangularia whitei var. praeceps x70



Genus GLOBOROTALITES Brotzen 1942

Genotype Globorotalia multisepta Brotzen 1936

Globorotalites cushmani Goel 1965

Pl. 12, figs. 4,5. Pl. 15, figs. 1,2.

1928 Rotalia micheliniana (d'Orbigny); Franke, (in part), p. 188, Pl. 17, fig. 11a,b.

1931 Globorotalia micheliniana (d'Orbigny); Cushman, p. 45, Pl. 6, fig. 8a-c.

1946 Globorotalia micheliniana (d'Orbigny); Cushman, pp. 13, 152-3, Pl. 63, figs. 2,3.

1961 Globorotalites michelinianus (d'Orbigny); Vasilenko, p. 58, Pl. X, fig. 2a-c, (non fig. 1.)

1965 " cushmani Goel, pp. 108-9, Pl. III. fig. 1, 2a-c.

1968 " michelinianus (d'Orbigny); Sliter, p. 119, Pl. 22, fig. 1a-c.

1975 " " (d'Orbigny); Robaszynski, in Colbeaux et al, p. 19, fig. 2.

Test free, trochospiral, plano-convex, spiral side flat to very slightly raised, umbilical side very strongly convex, deep central pseudo-umbilicus, periphery circular, angular, slightly carinate; chambers distinct, angular conical, gradually increasing in size;

sutures distinct, flush with surface, radial straight to slightly curved, oblique; wall smooth, calcareous, occasionally thickened to form a low boss in the centre of the spiral side; aperture elongate interomarginal slit from the base of the final chamber towards the periphery.

Max. dimensions: Diameter 0.48 mm. Thickness 0.28 mm.

Remarks: D'Orbigny stated in 1840 that one of the most important characters of Rotalia micheliniana was the lack of an umbilicus, yet ever since his description and figures illustrating this feature were published, numerous authors have used this trivial name for specimens which have a distinct, deep umbilicus.

Goel (1965) examined the original specimens designated by d'Orbigny to be Rotalia micheliniana, and housed in the Palaeontological gallery of the Museum National d'Histoire Naturelle in Paris. He states that there are two tubes of material; Tube A from Meudon and St.Germain and Tube B from Meru. Those specimens taken from Tube B were found to be typical of the original description in the absence of an umbilicus, whereas some of the specimens from Tube A do have an umbilical depression. Goel quite rightly follows the original designation of the species and states that the specimens of Tube B are the ones described and figured as R. micheliniana by d'Orbigny.

The synonomy listed here gives only a few of the more important references which have incorrectly placed specimens with an umbilicus into G. michelinianus (d'Orbigny). It is a common mistake and thus the present list is far from complete. A number of authors, including Franke (1928), describe forms both with and without an umbilicus within this species, making their nomenclature only partly correct.

In 1965 Goel erected the new species Globorotalites cushmani a form characteristic of the lower Senonian, with a deep, central, umbilical depression, and this name has been adopted here for those forms encountered in southern England. Globorotalites chaldonensis (Williams-Mitchell, 1948) could well be synonymous with G. cushmani, having an almost identical stratigraphic distribution and similar appearance. However, due to the poor diagrams and description of the 1948 material, this point is left open until the Williams-Mitchell specimens, which have priority, are redescribed.

Goel suggested that G. cushmani evolved from the earlier G.minuta Goel stock, although the forms are distinct, the umbilical region of the latter being very broad and shallow.

Robaszynski (1975) uses G. michelinianus for lower Senonian specimens, together with G. hangensis Vasilenko a broader, flatter form which has a more Turonian distribution.

Goels' work of 1965 divides the genus Globorotalites far too finely, on characters which are often very difficult to determine in many imperfect specimens. However, the presence of a deep umbilicus in the present species sets it apart from G. michelinianus (d'Orbigny) and the definition of G. cushmani has been followed here.

Range: Assemblage Zones A - F.

Genus GYROIDINOIDES Brotzen 1942

Genotype Rotalina nitida Reuss 1844

Gyroidinoides nitidus (Reuss) 1844

Pl. 12, figs. 6,7,8.

1844 Rotalina nitida	Reuss, p. 214.
1845 " "	Reuss; Reuss, p. 35, Pl. VIII, fig. 52, Pl. XII, figs. 8,20.

1860 Rotalia " (Reuss); Reuss, p. 222.

1891 " umbilicata var. nitida (Reuss); Beissel, p. 71, Pl. 14, figs. 14-19.

1914 " nitida (Reuss); Franke, p. 438.

1925 " soldani forma nitida (Reuss); Franke, p. 89, Pl. VIII. fig. 3.

1928 " " " " (Reuss); Franke, p. 187, Pl. XVIII, fig. 1a,b.

1929 " nitida (Reuss); Storm, p. 60.

1934 " " (Reuss); Brotzen, p. 72.

1934 Gyroidina " (Reuss); Morrow, p. 197, Pl. 30, fig. 1a-c.

1936 " " (Reuss); Brotzen, pp. 157-9, Pl. 11, fig. 3a-c, t. fig. 58.

1940 " " (Reuss); Brotzen, p. 32.

1941 " aff. nitida (Reuss); Marie, pp. 220-1, Pl. XXXIV, fig. 319a-c.

1942 Gyroidinoides nitida (Reuss); Brotzen, p. 19, fig. 6,3.

1943 Gyroidina " (Reuss); Frizzell, p. 351, Pl. 57. fig. 6a-c.

1946 " " (Reuss); Cushman, p. 140, Pl. 58, fig. 5.

1946 " " (Reuss); Schijfsma, p. 85, Pl. 5, fig. 1.

1957 " umbilicata (d'Orbigny); McGugan, p. 342, Pl. 33, fig. 4.

1964 Gyroidinoides nitida (Reuss); Loeblich & Tappan, p. C753, fig. 615,6.

1968 " nitidus (Reuss); Sliter, p. 121, Pl. 22, fig. 7.

1973 " " (Reuss); Koch, p. 212.

Test free, trochospiral, planoconvex to biconvex, the spiral side being low to almost flat, umbilical side strongly convex, sub-globular, periphery very broadly rounded; chambers elongate, rhomboidal in section, slightly inflated, increasing uniformly in size, approximately seven or eight in the final whorl; sutures flush to very slightly depressed, radial, straight to very slightly curved; wall smooth, perforate calcareous; aperture elongate, narrow slit along the inner margin of the final chamber, extending from the umbilical edge almost to the spiral end of the chamber; umbilicus open, partially obscured by small umbilical flaps, present on each chamber.

Max. dimensions: Diameter 0.58 mm. Thickness 0.38 mm.

Remarks: A common, long ranging form which probably arises from the Albian - Cenomanian species Gyroidinoides parva (Khan), the lineage between the two being discussed at some length by Jannin (1967) and again by Hart (1970).

The sub-globular, shape of the test, and rounded periphery are fairly distinctive in this species, although it may be mistaken for G. umbilicata (d'Orbigny) as was the case in McGugan (1957). The two are distinguished by the fact that G. umbilicata shows the development of small flaps, which may cover the umbilicus, as is normally seen in members of the genus Valvulineria.G. nitidus is also normally much more inflated.

Range: Assemblage Zones A - F.

Family ANOMALINIDAE Cushman 1927

Subfamily ANOMALININAE Cushman 1927

Genus GAVELINELLA Brotzen 1942

Genotype Discorbina pertusa Marsson 1878

Gavelinella ammonoides (Reuss) 1844 sensu lato

Pl. 12, figs. 9,10,11.

1844	Rosalina ammonoides	Reuss, p. 214.
1845	" "	Reuss; Reuss, p. 36, Pl. VII, fig. 53, Pl. XIII. fig. 66.
1862	Rosalina ammonoides	Reuss; Reuss, pp. 330-1.
1894	Anomalina "	(Reuss); Chapman, p. 722.
1925	" "	(Reuss); Franke, p. 86, Pl. VII, fig. 13.
1928	" "	(Reuss); Franke, p. 180, Pl. XVI, fig. 8a-c.
1934	" "	(Reuss); Brotzen, pp. 61-2.
1940	" "	(Reuss); Cushman, p. 28, Pl. 5, figs. 4,5.
1942	Gavelinella "	(Reuss); Brotzen, pp. 48-49, fig. 16.
1946	Anomalina "	(Reuss); Cushman, p. 154, Pl. 63, figs. 10,11.

Test free, slightly asymmetric planispiral, biumbilicate, margins rounded to sub-angular, with the occasional development of a broad peripheral keel, evolute on the spiral side, only final whorl of about nine chambers visible on the umbilical side; chambers distinct, un-inflated, gradually increasing in size; sutures raised as low ribs, radial, straight on the umbilical side and curved backwards on the spiral side; wall calcareous, coarsely perforate on the umbilical side, between the ribs, and also in the later chambers on the spiral side; aperture narrow slit, along the inner margin of the final chamber, from the periphery down the umbilical side into the umbilicus, umbilical end beneath a flap which extends from the base of each chamber, remnant flaps covering the umbilicus.

Max. dimensions: Diameter 0.62 mm. Thickness 0.36 mm.

Remarks: Brotzen (1942) gives a broad outline of the possible evolutionary lineages present in the genus Gavelinella, and although the work he carried out on the taxonomic status of the genus is of great value, the trends and distributions which he indicates do not conform with the situation studied in southern England.

The present broadly defined species probably includes forms regarded as G. costata Brotzen and G. lorneiana (d'Orbigny) elsewhere, together with late varieties of G. intermedia Berthelin.

The range of morphological variation exhibited by the group is quite broad and because of this it is difficult to define specific characters. As a whole it is not possible to use the species stratigraphically, although some of the variants have a sufficiently limited distribution to give them some significance in correlation.

Range: Assemblage Zones A - F.

Gavelinella ammonoides (Reuss) var. A.

Fig. 4:7.

Test free, asymmetric planispiral, evolute on spiral side, 8-9 chambers in the final whorl; chambers distinct, increasing uniformly in size, uninflated; sutures straight to slightly curved; wall calcareous, smooth, with a low, irregular boss covering the central area of the spiral surface; aperture, narrow slit on the umbilical side, along the inner, margin of the final chamber.

Max. dimensions: Diameter 0.58 mm. Thickness 0.24 mm.

Remarks: The basic morphology of this variety places it within the concept of G. ammonoides (Reuss) as given above. It is considered as being distinct on the basis of the irregular, flat, calcareous boss, situated in the centre of the spiral surface. This variety is rare and it appears to be restricted to the lower Santonian.

Range: Assemblage Zones E -F.

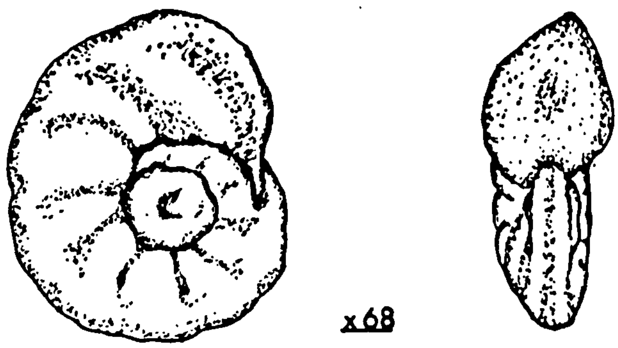


Fig. 4:7
G. ammonoides var. A.

Gavelinella cf. clementiana (d'Orbigny) 1840

Pl. 12, figs. 12,13,14.

1840 Rosalina clementiana d'Orbigny, p. 37, Pl. III. figs. 23-5.

1941 Discorbis " (d'Orbigny); forma typica Marie, p. 213, Pl. XXXIII, fig. 312 a-c.

1961 Anomalina (Pseudovalvulineria) clementiana var. clementiana (d'Orbigny); Vasilenko, p. 121, Pl. XXII, figs. 4a-c.

Test free, asymmetric planispiral to trochospiral, periphery rounded; chambers distinct in the final whorl, flat, uninflated, gradually increasing in size; sutures elevated on both sides to form distinct, radial ribs, curving backwards at the margins, spiral suture raised on the umbilical side, radial ribs joining it at right angles; wall coarsely perforate between the ribs on the umbilical side, smooth on the final whorl of the spiral side, towards centre of the spiral side there is a highly raised, large, irregular ornament completely covering early stages of the test; aperture small narrow slit on the inner margin of the final chamber, extending from the umbilical region onto the periphery.

Max. dimensions: Diameter 0.81 mm. Thickness 0.35 mm.

Remarks: An extremely distinctive species that is restricted to the uppermost part of the succession under consideration. On considering d'Orbignys' figures of G. clementiana, this species may be considered as being closely related, but there the affinity ends. The same comments are made when the illustrations of Discorbis clementiana, given by Marie (1941), are examined, however, this is not the case when this species is compared with Anomalina (Pseudovalvulineria) clementiana var. clementiana as recorded by Vasilenko (1961), as this variety is identical to those present in the English succession.

It is also interesting to note that Vasilenko uses this species as a middle to upper Santonian indicator, a distribution not all that dissimilar to that recorded here.

Range: Assemblage Zone F.

Gavelinella pertusa (Marsson) 1878

Pl. 13, figs. 1,2.

1878	Discorbina pertusa	Marsson, p. 166, Pl. 4, fig. 35 a-e.
1891	Rosalina ammonoides	Reuss; Beissel, p. 75, Pl. XVI, figs. 1-5.
1925	Anomalina pertusa	(Marsson); Franke, p. 86, Pl. VII, fig. 16a,b.
1928	" "	(Marsson); Franke, p. 182, Pl. XVII, fig. 4a,b.

1932 <u>" "</u> (Marsson); Cushman, p. 345, Pl. 51, fig. 15a-c.

1940 <u>Anomalina (?) "</u> (Marsson); Brotzen, p. 29.

1942 <u>Gavelinella pertusa</u> (Marsson); Brotzen, pp. 41-3, Pl. 1, figs. 1, 2. p. 6, t. fig. 1a-c. p. 18, t. fig. 6, fig. 2, t. fig. 14.

1946 <u>Anomalina "</u> (Marsson); Keller, p. 104, Pl. 1, figs. 7-9.

1948 <u>Gavelinella "</u> (Marsson); Brotzen, pp. 75, 6. figs. 4-6, t. fig. 20.

1953 <u>" "</u> (Marsson); Hagn, pp. 83-4, Pl. 7, fig. 14a-c.

1954 <u>Anomalina (Gavelinella) pertusa</u> (Marsson); Vasilenko, pp. 80-1, Pl. 8, fig. 3a-c.

1956 <u>Gavelinella pertusa</u> (Marsson); Hofker, p. 107, t. fig. 3a-c.

1957 <u>" "</u> (Marsson); Hofker, pp. 291-2, t. figs. 345-6, p. 306, t. fig. 363, p. 317, t. fig. 366.

1957 <u>Anomalina "</u> (Marsson); McGugan, Pl. 33, fig. 1a, b.

1964 <u>Gavelinella "</u> (Marsson); Loeblich & Tappan, p. C759, fig. 621, 5.

Test free, low trochospiral, partially evolute, especially on spiral side, distinctly rounded on peripheral margin; chambers distinct, circular in section, gradually increasing in size as added, eight or nine chambers in the final whorl; sutures flush to slightly depressed, indistinct, radial, straight; wall relatively robust, coarsely perforate; aperture arcuate slit following the inner margin of the final chamber from the umbilicus round onto the periphery; umbilicus distinct, open.

Max. dimensions: Diameter 0.47 mm. Thickness 0.28 mm.

Remarks: Opinions appear to differ as to the full stratigraphic range of this species. The majority of workers having described it from Campanian to Maastrichtian deposits. However, earlier workers including Franke (1925, 1928) and Keller (1946) have recorded it from lower Senonian horizons, which are more consistant with the distribution encountered here.

Range: Assemblage Zones A - F.

Gavelinella. thalmanni (Brotzen) 1936

Pl. 13, figs. 3,4,5.

1936 Cibicides thalmanni Brotzen, pp. 190-1, Pl. 14, fig. 7a-c.

1961 Anomalina (Pseudovalvulineria) thalmanni (Brotzen); Vasilenko, p. 119, Pl. XXII, figs. 2,3.

1966 Gavelinella thalmanni (Brotzen); Barr, pp. 506-7, Pl. 78, fig. 1a-c.

1973 " " (Brotzen); Koch, p. 213.

Test free, slightly compressed trochoid, appearing almost planispiral, dorsal side weakly compressed with shallow umbilicus, ventral side distinctly flattened, umbilicus present, covered by apertural flaps, approximately two whorls visible on the dorsal side, margin rounded; chambers indistinct, not inflated, increasing gradually in size, 11 or 12 in the final whorl; sutures flush, indistinct, straight, radial; wall smooth on ventral side, coarsely perforate, on dorsal side slightly raised rugose ribs are present, providing an irregular nodose ornament; aperture interomarginal slit, extending from the periphery into the umbilical area of the ventral side, covered by a well developed flap.

Max. dimensions: Diameter 0.42 mm Thickness 0.13 mm.

Remarks: A useful stratigraphic marker, easily distinguished from other members of the Gavelinella group by the flattened nature of the ventral side, and the wide, shallow dorsal umbilicus.

Barr (1966) notes the presence of G. thalmanni in the chalk of Eire and also its appearance in the M. cortestudinarium Zone of southern England, indicating that it ranges as high as the Belemnitella mucronata Zone.

Vasilenko (1961), however regards this species as being a useful stratigraphic marker for his Anomalina infrasantonica Zone, corresponding to the Lower Santonian.

Range: Assemblage Zones B - F.

Gavelinella tumida Brotzen 1942

Pl. 13, figs. 8, 9.

1936	Anomalina lorneiana	(d'Orbigny); Brotzen, p. 178, Pl. 12, figs. 1, 2.
1942	Gavelinella tumida	Brotzen, pp. 47-8, fig. 15.
1970	" "	Brotzen; Porthault, in Donze et al, p. 59, Pl. 8, figs. 13-15.
1973	" "	Brotzen; Norling, in Bergström et al, p. 112, Pl. 8, figs. 2, 3.

Test free, low trochospiral, dorsal side flat, ventral side involute, slightly convex, deeply umbilicate, margins rounded; chambers distinct, increasing rapidly in size, final two to three extremely inflated; sutures straight, radial, becoming constricted where the chambers are inflated, wall, smooth, perforate, calcareous; aperture slit to low arch extending from the periphery into the umbilicus.

Max. dimensions: Diameter 0.48 mm. Thickness 0.31 mm.

Remarks: This species has a rather patchy distribution in this country except in the lower half of the succession on the Isle of Wight. It is present in a few samples in the Santonian of south - east, Kent particularly around the junction of Assemblage Zones D and E.

Porthault (1970) records an upper Coniacian to lower Santonian range in southern France, and this appears to be reasonably consistant with the present findings.

Range: Assemblage Zones A - E.

Gavelinella sp. A.

Pl. 13, figs. 6, 7.

Test free, compressed trochospiral, becoming almost planispiral, both dorsal and ventral sides flattened, margins rounded; chambers distinct, uninflated, increasing gradually in size, nine or ten in final whorl; sutures distinct, flush with surface, radial, curving backwards slightly at the margins; wall calcareous, coarsely perforate in scattered areas on the ventral side; aperture narrow extra-umbilical to umbilical slit, covered by a small apertural flap at the base of the final chamber, remnant flaps infill the umbilicus in a radiate pattern.

Max. dimensions: Diameter 0.42 mm. Thickness 0.17 mm.

Remarks: Due to its limited distribution within the scope of the present study, Gavelinella sp. A. has proved to be of some value in correlating a few sections.

The general morphology of this species is similar to that of the Gavelinella intermedia (Berthelin), although this species has an Albian to Cenomanian range. Brotzen (1942) illustrates several lineages originating from G. intermedia, including the trend which includes G. ammonoides and G. costata, and it is thought that this species is probably a later, Santonian member of the same evolutionary branch.

Range: Assemblage Zone F.

Gavelinella sp. B.

Pl. 13, figs. 10, 11, 12.

Test free, trochospiral, biconvex, periphery rounded, slightly angled; chambers only visible in final whorl of seven or eight, increasing in size uniformly; sutures curved, radial and slightly depressed in later chambers; early chambers totally masked by the presence of a large umbilical boss, domination the central part of the test; wall smooth, calcareous; aperture elongate slit following the spiral suture on the ventral side on to the peripheral edge.

Max. dimensions: Diameter 0.59 mm.. Thickness 0.30 mm.

Remarks: The examples of this species found in the present study are thought to be very closely related to Gavelinella tourainensis Butt, described from the type Turonian. The lineage to which this belongs appears in the Gault with Gavelinella reussi (Khan), a name applied to the species which includes within its synonomy Anomalina complanata (Reuss) and Gavelinopsis berthelini (Keller), both refered to by numerous authors. Butt (1966) uses the name G. tourainensis for the Turonian member of this group, and the present form is merely a late example of the same lineage.

It is notable that the characteristic of a large centrel umbilical boss is continued by the Cibicides voltziana (d'Orbigny) group, present higher in the Senonian, and this may be an even later extension of the same evolutionary trend seen in the Cenomanian and Turonian. The species which Vasilenko records as Anomalina (Brotzenella) menneri Keller, from the Maastrichtian of the Mangyschlak peninsula also shares the same gross morphology.

Range: Assemblage Zone A.

Gavelinella sp. C.

Pl. 13, figs. 13,14,15.

Test free, very low trochospire, almost planispiral, both dorsal and ventral sides are flat, very shallow umbilicus on the dorsal side, infilled by remnant apertural flaps on the ventral side; chambers low, increasing uniformly in size; sutures flush with surface, radial, slightly curved; wall smooth, calcareous, aperture narrow interomarginal slit, extending from the periphery to the umbilicus on the ventral side, beneath a small flap at the base of the chamber.

Max. dimensions: Diameter 0.43 mm. Thickness 0.18 mm.

Remarks: Brotzen (1942) illustrated G. ammonoides (Reuss) by simply enlarging the original type figures, and goes on, as mentioned above, to give Reuss' species a Turonian range. The present species is believed to belong within Brotzens' concept of a typical Turonian example of G. ammonoides (Reuss), although the present concept of that species is somewhat broader. Gavelinella sp. C has been retained as a separate entity therefore, and is probably an early form of G. ammonoides sensu lata, as defined in the present study.

Range: Assemblage Zone A.

Genus LINGULOGAVELINELLA Malapris 1965

Genotype Lingulogavelinella albiensis Malapris 1965

Lingulogavelinella sp. A

Pl. 14, figs. 1,2,3.

1975 Gavelinella aff. vombensis 2 (Brotzen); Robaszynski, in Colbeaux et al, p. 19, fig. 2.

Test free, low trochospire, forming an asymmetric planispiral shape in section, margin rounded, early whorls masked on dorsal side by a calcareous boss, ventral side is involute; chambers distinct only in final whorl, gradually increasing in size, sub-angular at the periphery; sutures flush to slightly depressed on the dorsal side, raised to form low septal ribs on the ventral side, slightly curved at the margin, radially arranged; wall calcareous, smooth on the dorsal, coarsely perforate in between the septa on the umbilical side; aperture narrow, interomarginal slit, covered by an apertural flap on the ventral surface, extending from the periphery into the umbilical area; umbilicus filled by remnant apertural flaps at the base of each of the septal ribs, forming a radiate pattern in the central part of the ventral side.

Max. dimensions: Diameter 0.68 mm. Thickness 0.33 mm.

Remarks: A distinctive form, of much stratigraphic value, and has far as is known, one which has not been described previously. It has been placed within the genus Lingulogavelinella, following the generic description given by Malapris (1965); the radiate pattern on the umbilical side being characteristic of the group.

After an extended search through as much of the relavent literature as could be covered, few similar forms were encountered, and these are almost entirely members of the genus Pseudovalvulineria, a name suppressed by Loeblich & Tappan (1964), and included within the Gavelinella group.

Two species are noted as very closely resembling the present form, these are Pseudovalvulineria glabra (Goel) and Anomalina (Pseudovalvulineria) clementiana (d'Orbigny) var. usakensis Vasilenko, both described from the Campanian. The first was illustrated by Goel (1965, Pl. IX, fig. 1a-c) and from these figures the similarities with the present form are obvious, however the ventral side is by no means as perforate as the present species, and more importantly the radiate pattern of the umbilical region is absent.

This difference in umbilical configuration is also the differing feature in Vasilenkos' new variety of Gavelinella clementiana (d'Orbigny). This form has a central boss which is visible on both the dorsal and ventral sides, which alters the appearance of the umbilicus, when compared with Lingulogavelinella sp. A.

A further form which has been proved to be the same as the present species is Gavelinella aff. vombensis (Brotzen) as figured by Robaszynski (1975). Dr. Robaszynski kindly loaned several examples of this species to the present author, which confirmed that the two were con-specific. It is agreed that Brotzens (1945)species Pseudovalvulineria vombensis is very close to the present form, although it was first recorded from the Lower Campanian of southern Sweden. It would therefore seem that Lingulogavelinella sp. A. may be the ancestral form of the Swedish species and that Gavelinella aff. vombensis (Robaszynski) should be included within the synonymy, especially as its distribution closely parallels that of the English species.

The previously described stratigraphic range of the genus Lingulogavelinella is extended by the present form, as its nearest relative is L. globosa (Brotzen), found in the lower part of the Turonian in this country, but undescribed from any higher. It is thought that the present species is the lower Senonian continuation of this L. globosa stock.

The range of Lingulogavelinella sp. A is of prime importance within the scope of the present work, as its spread from the top part of Assemblage Zone A to the upper limit of Assemblage Zone D, broadly equates with the concept of the Coniacian in this country as defined by Casey et al (in press), with a slight overlap at either end. The disappearance of this species at the above zonal boundary is quite distinctive, since up to this point the species shows an increasing abundance in the benthonic population, until reaching well over 30% of the total benthonic assemblage. It then becomes almost totally absent from the succession except for very rare individuals which are found in Assemblage Zone E.

Range: Upper part of Assemblage Zone A to the base of Assemblage Zone E.

Genus STENSIOINA Brotzen 1936

Genotype Rotalia exsculpta Reuss 1860

Stensioina exsculpta exsculpta (Reuss) 1860

Pl. 14, figs. 4,5,6.

1860	Rotalia exsculpta	Reuss, p.78, Pl. XI. fig. 4.
1936	Stensioina "	(Reuss); Brotzen, pp. 165-6. Pl. 11, fig. 8.
1940	" "	(Reuss); Cushman & Dorsey, p. 2, Pl. 1, figs. 1-3.
1942	" "	(Reuss); Brotzen, p. 20, fig. 6, 8.
1945	" "	(Reuss); Brotzen, p. 52, t. figs. 8D, E.
1948	" "	(Reuss); Williams-Mitchell, p. 104, Pl. 9, fig. 10.
1954	" "	(Reuss); Pozaryska, p. 264, fig. 22A-C.
1957	" "	(Reuss); McGugan, pp. 341-2, Pl. 33, fig. 3.
1958	" "	(Reuss); Jirova, p. 225, Pl. 1, fig. 1.
1961	" "	(Reuss) Vasilenko, pp. 65-6, Pl. XI, fig. 4a,b.

1962 ______"______" gracilis Brotzen; Hiltermann & Koch, p. 324, Pl. 49, figs. 13, 14.

1964 ______"______" (Reuss); Cita, figs. 1-3 (non fig. 4).

1968 ______"______" exsculpta (Reuss); Trümper, pp. 25-6, Pl. VIII, figs. 1-4, Pl. IX, fig. 1a-c.

1970 ______"______ praeexsculpta (Keller); Porthault, in Donze et al, (in part), pp. 59-60, Pl. figs. 16-9.

Test free, biconvex to plano-convex, the spiral side often being almost flat, involute on ventral side, dorsal side is evolute, approximately $2\frac{1}{2}$ whorls being visible, margins acutely angled; chambers distinct, sub-rectangular, gradually increasing in size; sutures distinct on dorsal side, raised sharply forming elevated septal ridges, this ornament is also present on the spiral suture, on ventral side flush to slightly depressed, curved backwards slightly at the margin; wall calcareous ornamented on spiral side, ventral side is coarsely perforate in between the septal areas, which are smooth; aperture elongate slit along the inner, ventral margin of the final chamber.

Max. dimensions: Diameter 0.53 mm. Thickness 0.15 mm.

Remarks: The stratigraphic value of this genus is discussed later in greater detail.

This species is distinguished from S. granulata (Olbertz), with which it coexists, in having a much more sharply angled peripheral edge, and in having a more distinctive ornament on the spiral surface.

It is believed to be at the lower end of an evolutionary lineage which leads into S. exsculpta gracilis Brotzen, and towards the upper part of the succession studied, transitions between the two forms are very common.

Range: Lower part of Assemblage Zone B to Assemblage Zone F.

<u>Stensioina exsculpta gracilis</u> Brotzen 1845

Pl. 14, figs. 7,8.

1945 <u>Stensioina exsculpta</u> var. <u>gracilis</u> Brotzen, p. 52, Pl. 1, fig. 15,

1957 <u>" "</u> var. <u>aspera</u> Hofker, pp. 349-350, fig. 401-3.

1958 <u>" " gracilis</u> Brotzen; Pokorny, p. 307, t. figs. 13,14.

1962 <u>" " "</u> Brotzen; Hiltermann & Koch, p. 324, Pl. 49, figs. 13,14.

1962 <u>Stensioina exsculpta</u> (Brotzen); Hiltermann & Koch, pp. 325-6, Pl. 49, figs. 15-18.

1968 <u>" " gracilis</u> Brotzen; Trümper, p. 26, Pl. IX fig. 2, Pl. X, figs. 1-3, Pl. XI, figs. 1,2,5.

1970 <u>" gracilis</u> Brotzen; Porthault, in Donze et al, p. 60, Pl. 8, figs. 20,21.

Test free, biconvex, spiral surface being highly raised, involute on ventral side, evolute on dorsal side, margins acute; chambers distinct, sub-rectangular, increasing uniformly in size; sutures distinct, with raised septal ridges on dorsal side, elevated to form a rugose ornament towards the centre; wall calcareous, strongly perforate on ventral side; aperture, narrow slit along the inner margin of the final chamber.

Max. dimensions: Diameter 0.53 mm. Thickness 0.27 mm.

Remarks: This sub-species of S. exsculpta. when found in its' originally described form, differs very markedly from S. exsculpta exsculpta in being extremely biconvex. In S. exsculpta gracilis the test becomes much more trochoid and the spiral suture is very highly raised, such that the centre of the spiral side bears an elevated calcareous ornament.

True members of S. exsculpta gracilis do not occur in this country until well into the Uintacrinus socialis Zone, and higher than the sections described here. However, transitional members of the S. exsculpta exsculpta – S. exsculpta gracilis lineage were encountered in some abundance and many of these were classified as S. exsculpta gracilis as they had become much too trochoid to be classified as S. exsculpta exsculpta.

Range: Assemblage Zone F.

Stensioina granulata (Olbertz) 1942

Pl. 14, figs. 9,10,11,12.

1935	Gyroidina praeexsculpta	Keller, Pl. 3, figs. 28-32.
1942	Rotalia exsculpta granulata	Olbertz, pp. 132-3, Pl. 5, fig. 2.
1945	Stensioina prae-exsculpta	Keller; Brotzen, pp. 52-3, Pl. 1. figs. 16,17.
1954	" praeexsculpta	(Keller); Pozaryska, p. 265, fig. 23.
1956	" "	Keller; Hiltermann & Koch, Tab. 3, Pl. 1. fig. 7.
1957	" prae-exsculpta	(Keller); Hofker, p. 345, figs. 394,395.
1957	" "	var. granulata (Olbertz); Hofker, pp. 345-7. figs. 394,395.

1958 " *polonica* Witwicka, pp. 206-7, 265-7, Pl. 12, figs. 21, 22, Pl. 13, fig. 23.

1962 " *praeexsculpta* (Keller); Hiltermann & Koch, p. 323, Pl. 49, figs. 10, 11.

1962 " *exsculpta granulata* (Olbertz); Hiltermann & Koch, pp. 323-4, Pl. 51, figs. 1, 2.

1966 " *praeexsculpta* (Keller); Salaj & Samuel, pp. 147-8, Pl. 32, fig. 1a, b.

1968 " *granulata* (Olbertz); Trümper, pp. 10-14, Pls. 1-3, Pl. 12, figs. 1-3.

1970 " aff. *granulata* (Olbertz); Porthault, in Donze et al, pp. 60-1, Pl. 8, figs. 22, 23.

Test free, low trochospiral, dorsal side flat, ventral side strongly convex and involute, periphery rounded; chambers distinct on ventral side only, increasing uniformly in size, nine to ten in the final whorl; sutures indistinct on dorsal side, slightly depressed around the margin, elevated as low broad septal ridges on the ventral side, straight, radial; wall calcareous, dorsal side rugose granular ornament covering whole surface, ventral side coarsely perforate in between the septal ribs, periphery smooth; aperture narrow intero-marginal slit following the ventral edge of the final chamber, umbilicus shallow covered by calcareous plate.

Max. dimensions: Diameter 0.45 mm. Thickness 0.18 mm.

Remarks: As can be seen from the synonymy *Stensioina prae-exsculpta* (Keller) has been considered as being conspecific with *S. granulata* (Olbertz), following the work of Trümper (1968). He notes that in the original designation of *Gyroidina praexsculpta* by Keller (1935) no description, or any indication of previous descriptions, were given and he therefore considers this species name to be invalid.

Brotzen (1945), in a useful discussion regarding the close affinity of the two species, mentions the variation in the ornament in what he regards as S. prae-exsculpta Keller. He records that this species lacks a sculpture on the last few chambers, whereas it is continuous in S. granulata, covering the whole dorsal side.

Brotzen notes the fact that Kellers' figures are poor and an accompanying description is absent. He goes on to state that "It is quite possible that S. prae-exsculpta and S. granulata are referable to one and the same species." This being the case, and because of the lack of a type description for S. prae-exsculpta (Keller), this species is included within the concept of S. granulata (Olbertz).

The importance of the first appearance of S. granulata in the English succession is extremely high, because of its' use as a stratigraphic marker in northern Europe, this is discussed more fully below.

Range: Assemblage Zones B to E.

Stensioina granulata (Olbertz) 1942 var. A.

Pl. 14, figs. 13, 14, 15.

Test free, trochospiral, ventral side identical to that of Stensioina granulata, variation occurs in the ornament on the dorsal side. This is not developed to the same degree of complexity as that seen in the typical form, low, smooth ribs are visible along a few of the later chambers, the granular, nodose ornament is also only weakly developed. There is also a slight tendency for the later chambers to become a little more angular at the margin.

Max. dimensions: Diameter 0.42 mm. Thickness 0.17 mm.

Remarks: From the basic morphological appearance of this form it should be placed within the species S. granulata (Olbertz). However, because of its' consistant use stratigraphically it is believed that it should be considered as a separate variety.

Range: Assemblage Zones D - F.

Stensioina sp. A.

Pl. 14, figs. 16,17,18.

Test free, low trochospire, flat on spiral side, slightly convex on the ventral side, periphery narrow, angular; chambers distinct on both sides, uninflated, gradually increasing in size, nine in final whorl; sutures flush on dorsal side, slightly raised on the ventral side, radial, straight; wall calcareous, distinctly smooth on the dorsal side, perforate on the umbilical side; aperture narrow intero-marginal slit along the ventral side of the final chamber; umbilicus extremely shallow, hardly developed.

Max. dimensions: Diameter 0.43 mm. Thickness 0.15 mm.

Remarks: An extremely rare form with only one definitely identified specimen being found in the present study. The relatively small thickness in side view and the angular nature of the periphery would suggest that this belonged to the S. exsculpta group. However the total lack of any ornament on the spiral side, rules out this possibility and indicates an early offshoot from the S. granulata lineage.

It is suggested here that this form could well be transitional between the S. granulata and the S. exsculpta lineages, a link which was postulated by Trümper (1968).

Range: Assemblage Zone A.

Discussion of the Stensioina group.

The Stensioina group is believed to originate in the Middle to Upper Turonian, and this has been well documented by continental authors such as Keller (1935), Brotzen (1945), Pozaryska (1954), Koch (1966, in Ernst et al), and Trümper (1968).

Those earlier forms previously referred to S. prae-exsculpta (Keller) are here included within S. granulata (Olbertz) and it is these which form the ancestral basis for the genus. However, it should be noted that this ancestral stock has not yet been recorded from the Turonian of this country.

In southern England the earliest record of S. granulata falls on the junction between Assemblage Zones A and B; the appearance of this species being a useful indicator in the positioning of this boundary. This species is then present in the rest of the succession through to Assemblage Zone E, although examples of S. granulata var.A continue to be found above this level.

Stensioina exsculpta exsculpta appears for the first time some twelve to fifteen metres above S. granulata towards the base of Assemblage Zone C. This new lineage runs parallel with that of S. granulata through the rest of the succession under study, the relative proportions of each group varying persistantly. Towards the top of the succession, early transitional forms of S. exsculpta gracilis have been found in small numbers, identified by the height of the ornament in the centre of the spiral side.

The trend towards the *gracilis* subspecies is only seen around the top of Assemblage Zone E and in rare samples from Zone F. This therefore has a range commencing in the lower to middle Santonian.

At the same time as this, the appearance of *S. granulata* var. A. is noted, first recorded at the lower limit of Assemblage Zone D, and acting as a useful marker for this datum. The main line of this *S. granulata* lineage continues to evolve through the Senonian giving rise to typical *Stensioina pommerana* Brotzen around the Campanian - Maastrichtian boundary (Trümper 1968).

All these evolutionary trends were illustrated by Trümper (1968: fig. 17), and the lines which he suggests equate well with the situation which has been encountered in the English Chalk. For this reason, Figure 4:8 is an adaption of that given by Trümper for material from the Central European succession. It is interesting to note that only three areas of the lineages illustrated by Trümper are left with any uncertainty, two of these fall at the beginning and the end of the generic line, in the Turonian and at the base of the Danian respectively.

The third area of doubt is the link between the *S. granulata* lineage and that of the *S. exsculpta* group, and it is tentatively suggested that the form designated as *Stensioina* sp. A. could provide a possible transition across that gap. Only one specimen was found which was placed within this species, but the preservation was good and characters used for identification were clearly visible. This specimen was found at the base of the *M. cortestudinarium* Zone in S.E. Kent and falls in the lower part of the Coniacian as given by Casey et al. (in press), which is precisely the level that Trümper suggested for this evolutionary branch.

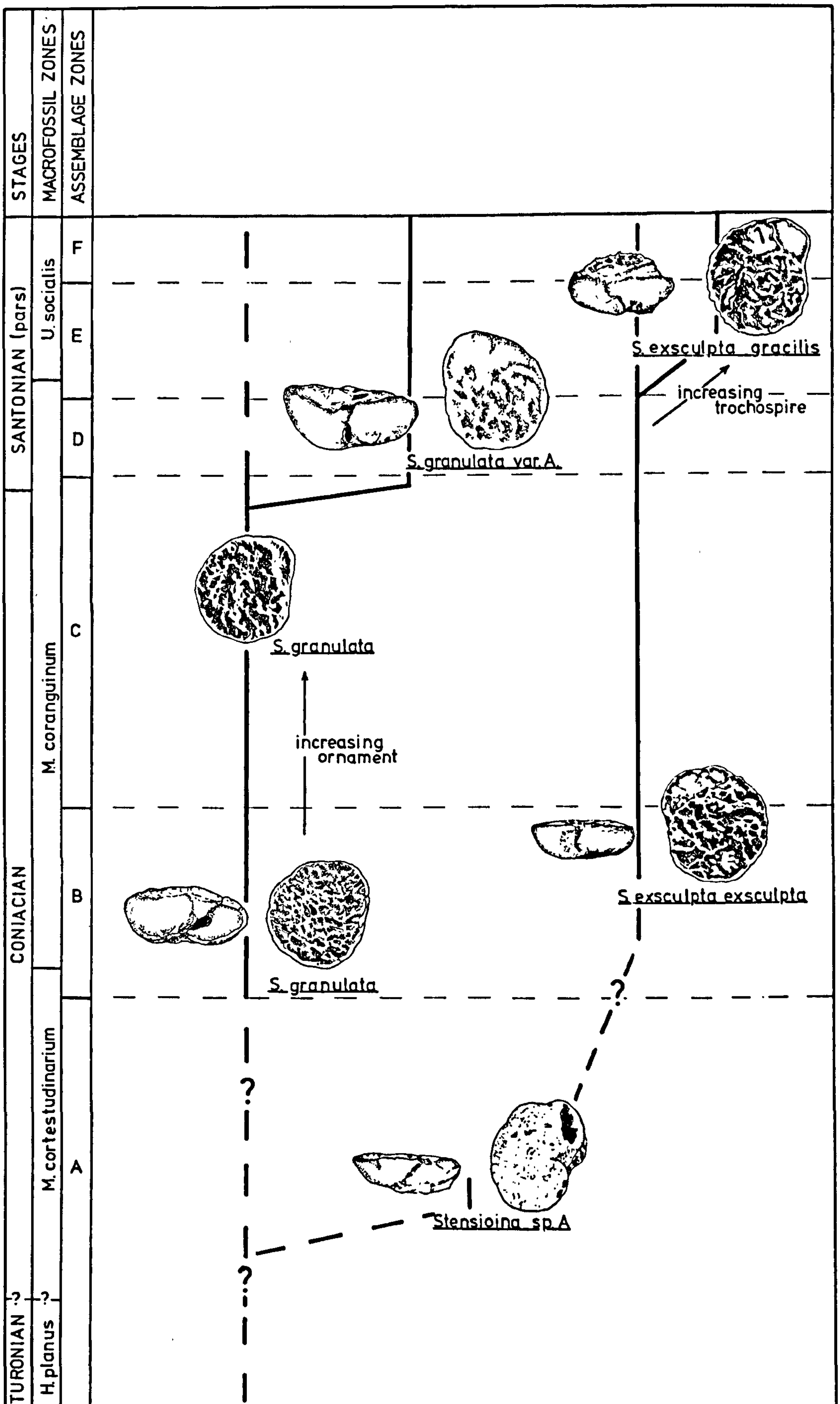


Fig. 4:8 Lower Senonian evolutionary trends in the genus Stensioina

Further work is required on the group as a whole from the English succession, particularly at the lower end of the *Stensioina* lineage to establish whether the transitions from one group to another suggested here are correct or not. The stratigraphic significance of the different members of the genus, noted in the English Chalk by Williams-Mitchell (1948), cannot be overemphasised both for use on a regional scale and also for discussion on an international basis.

CHAPTER 5.

ZONAL SCHEME

In any attempt to divide a succession into stratigraphic units a consistant, logical plan must be evolved on which that division may be based. The factors used to create the units must be easily recognisable and must facilitate the use of the scheme by any geologist working on that part of the succession. The proposed zonation evolved during the course of this research with the above criteria as basic principals.

5:1 Benthonic Foraminiferal Assemblage Zones

The use of assemblage zones, rather than zones defined on the range of an individual species, was considered more suited to a succession in which many of the more important species have fairly long ranges. Thus, a zone is characterized by the association of a distinct group of species and is classified by a letter. The lower Senonian of southern England can be divided much more accurately using this method.

The fauna at the base of the succession studied is notably restricted, and its lack of diversity, provides a useful criterion in separating it from the overlying units. Above this, there is a uniform increase in diversity, with four more marked faunal breaks. The addition of new taxa at these breaks, and also throughout the rest of the succession, provide the stratigraphic markers used in the zonation.

The Assemblage Zone limits proposed in this scheme are founded, for the most part, on the first appearances of groups of unrelated species. Each boundary therefore, indicates a recognisable change in the fauna. The first appearances of these species may not be entirely synchronous in the different sections studied, due to slight geographical variations in distribution and the limitations of the sampling method. It has therefore been necessary, at times, to construct a line showing the "best-fit" in order to draw a boundary between adjacent zones.

The relationship of this zonation to the equivalent macrofaunal divisions, and the more recent ideas concerning the stages of the Upper Cretaceous, is given in Fig. 1:1. Full details of the zonal indicators are given in Fig. 5:1.

Recognition of the individual assemblage zones is based primarily on the following criteria:-

Assemblage Zone A: The general abundance of long ranging lituolids such as Arenobulimina spp. and Marssonella oxycona, in association with Globorotalites cushmani, Reussella kelleri, Gavelinella sp. B., Gavelinella sp. C. and Verneuilina münsteri. An indicator for the upper limit of this zone is the disappearance of R. kelleri from the 250 micron size fraction.

Assemblage Zone B: Lingulogavelinella sp. A appears prior to the lower limit of this zone, which is defined on the appearance of Stensioina granulata, Gavelinella thalmanni and Cibicides sp. A. These are followed rapidly by Osangularia whitei var. whitei

Assemblage Zone C: Characterized by the association of Stensioina exsculpta exsculpta and Loxostomum eleyi with more rarely, Vaginulinopsis scalariformis. Praebulimina reussi appears towards the top of this zone.

Assemblage Zone D: Lower limit marked by the appearance of Stensioina granulata var. A., Cibicides beaumontianus and Eouvigerina sp. C. Eponides cf. concinna is also found higher in this zone.

Assemblage Zone E: Marked by the increased abundance of C. beaumontianus, with C. beaumontianus var. A and C. ribbingi. Pyramidina cf. buliminoides appears in the fine fraction and Reussella kelleri reappears in the 250 micron size range. Lingulogavelinella sp. A becomes extinct at the base of this zone.

Assemblage Zone F: Distinguished by the association of Gavelinella cf. clementiana, Reussella szajnochae praecursor, Osangularia whitei var. praeceps, Quadrimorphina trochoides and Cassidella sp. A.

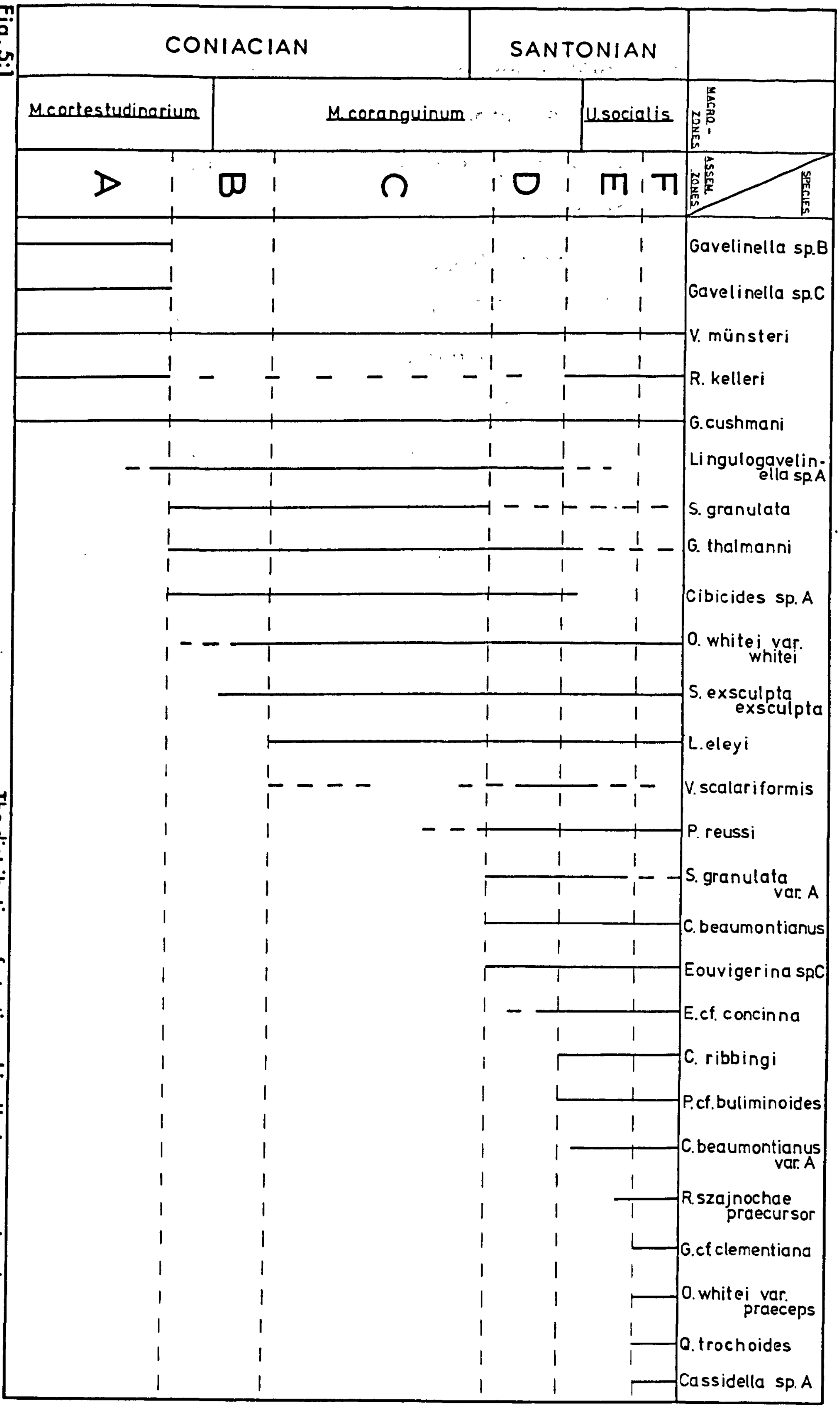


Fig. 5:1 The distribution of stratigraphically important benthonic species

This scheme is proposed merely to act as a tool in the correlation of the lower Senonian succession of southern England. Its relationship to the faunal assemblages documented from the Upper Cretaceous of Europe is considered later. Beyond the region studied, the recognition of any biostratigraphic zonation becomes more tentative.

5:2 Planktonic Foraminiferal zonation

The use of members of the Globigerinacea in order to create a global foraminiferal zonation has long been established, the works of Bolli (1957, 1959), Bandy (1967), Pessagno (1967) and Porthault (1974) being of particular value. More recently van Hinte (1972, 1976) has attempted to bring the foraminiferal zonation of the Upper Cretaceous into line with the geochronological time scale, using palaeomagnetic data and absolute age dating.

The majority of the planktonic species described in this work range throughout the succession. Often they are part of evolutionary lineages which vary only slightly through this period, such as the *G. marginata* - *G. bulloides* plexus, and the members of the Heterohelicidae. These are of little value in the recognition of stratigraphical divisions.

Fortunately, the sporadic appearance of species such as *G. renzi* and *G. concavata* prove to be very valuable as both have been used by van Hinte (1976) in his zonation of the lower Senonian.

The lower part of the Coniacian is defined on the presence of *G. renzi*, a range which equates well with that shown in van Hinte's scheme, although an occurrence of the species at Quidhampton extends the present range of the base of the Santonian.

G. concavata first appears in southern England near to the base of the M. coranguinum Zone, within Assemblage Zone B. Barr (1962) notes that the species ranges through the M. coranguinum Zone, a view endorsed here, as it has been recorded at Quidhampton and at the base of a borehole at Kelveden, Essex, which proved to be within Assemblage Zone F. A further useful species is G. primitiva, first described from the lowest Santonian (Dalbiez 1955). Its present range is here extended down into the Coniacian.

Members of the genus Globigerinelloides also occur, although not in abundance. G. asperus has too long a range to be of much value, but G. ehrenbergi and G. rowei as described by Barr (1962) are of note. Both have ranges between the top of Assemblage Zone B and the lower part of Assemblage E. G. rowei appears slightly later than G. ehrenbergi and has a longer range, a distribution which agrees well with that of Barr.

The ranges of the planktonic species are summarised in Fig. 5:2, which is a compilation of data from all the sections studied; this is also the case in Fig. 5:1.

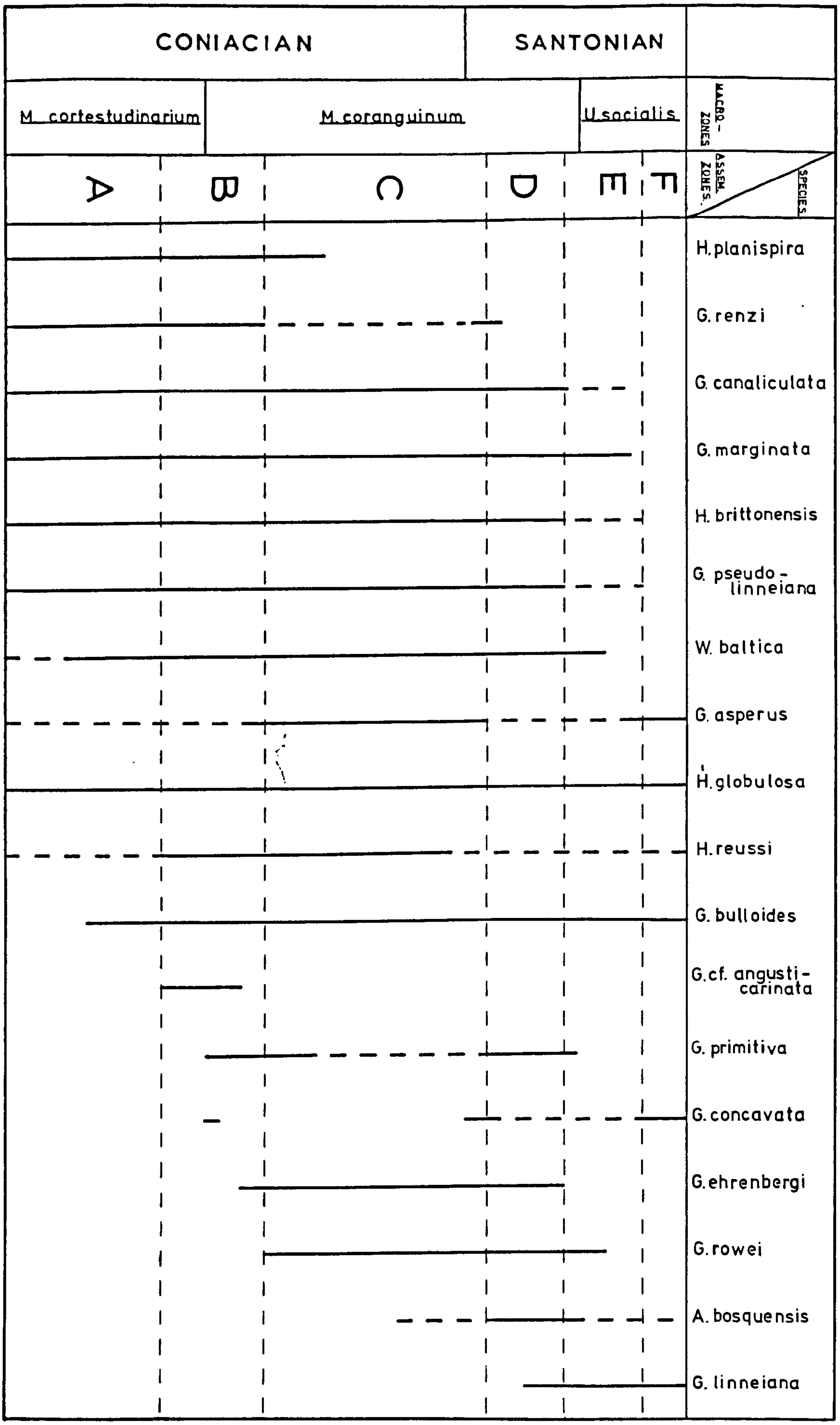


Fig. 5:2 The stratigraphic distribution of planktonic species

CHAPTER 6.

STRATIGRAPHIC DISCUSSION

Each section is discussed with reference to the total foraminiferal fauna recorded, and each is zoned accordingly. Comments have been made on the relative positions of macrofossil zonal boundaries and comparisons made with the detailed microfaunal analysis. Discrepancies, where they occur, have been discussed. For example, the upper limit of the M. coranguinum Zone at Culver Cliff, Isle of Wight (Rowe 1908), is questioned, as it has been on a number of previous occasions (Brydone 1914, Barr 1962).

There are three sections in which all the Assemblage Zones, except Assemblage Zone F, are present. This latter zone is only recorded at Culver Cliff and in two separate borehole samples from Essex provided by the Institute of Geological Sciences. The other six sections represent short intervals within the succession studied, and these are zoned accordingly.

Each section has been illustrated in the text, giving the ranges of the more important zonal species and the positions of the proposed zonal boundaries. Range charts of the total foraminiferal assemblages are presented as Enclosures 3-7.

Finally, the information is summarised on Enclosure 1 which is an attempt to correlate all the sections studied.

6:1 South east Kent.

The pattern of faunal distribution is established early in the section by the dominance of a few species, notably Lenticulina rotulata, Arenobulinina obliqua, Verneuilina münsteri, Globorotalites cushmani and Gyroidinoides nitidus. These five species, with the addition of Gavelinella ammonoides slightly higher in the section, form the major part of the foraminiferal fauna throughout the succession.

In addition to this group, there are several other long ranging species which, although not quite so abundant, are consistant members of the population. These include Gavelinella pertusa, Marssonella oxycona, Ataxophragmium variabile and Valvulineria lenticula. Neoflabellina praerugosa and N. baudouiniana appear just above the base of the section and are present through the rest of the succession.

These then are the predominant fauna of Assemblage Zone A, although it is defined by the presence of three other species, Gavelinella sp. C., Gavelinella sp. B. and Reussella kelleri. The second is a late form of the Gavelinella tourainensis lineage present in the Turonian. The last, R. kelleri, acts as a useful marker for the upper limit of the assemblage zone. Up to this point it is found continuously in the 250μ - 500μ size fraction. Above the boundary it is present only in the fine fraction, apart from sporadic occurences of larger specimens. This peculiar break in the distribution of large examples of the species has also been noted in both Borehole No. 25 and Borehole No. 52 of the Thames Barrier Site Investigation (Carter & Hart, in press A) which suggests that it may be of regional significance.

Seven metres up from the base of the section Stensioina sp. A is encountered. This early member of the genus is an extremely rare forerunner of the main Stensioina lineage, which commences at the base of Assemblage Zone B, with the appearance of S. granulata.

Towards the top of Assemblage Zone A Eouvigerina aculeata is recorded for the first time, and is then present for the remainder of the succession, giving it a range similar to that noted by Williams-Mitchell (1948). The closely related species E. stormi is recorded lower in the section and the extinction of this species at the junction of Assemblage Zones C and D is a useful marker in the south east Kent section.

Six metres below the junction of the Micraster zones (Rowe 1901), Lingulogavelinella sp. A appears for the first time. This species has a remarkably consistant range which can be correlated across each of the sections studied and effectively defines the M. coranguinum Zone of southern England. Approximately 3.5 metres below the base of this zone, in the Langdon Stair section (Rowe op. cit) the junction of Assemblage Zones A and B is drawn, marked by a distinct marl seam. This horizon marks a major microfaunal break, as above it four important species occur for the first time; Stensioina granulata, Gavelinella thalmanni, Cibicides sp. A. and Osangularia whitei var. whitei, the last appearing slightly higher than the other three.

Throughout Assemblage Zone A the planktonic foraminiferal fauna remains consistant, represented by Globotruncana pseudolinneiana, G. marginata, G. bulloides, Whiteinella baltica, Hedbergella brittonensis and H. planispira. This last species becomes extinct within Assemblage Zone B. The proportion of these species, when compared to that of the benthonic population is not high, except for a peak of around 20% of the total assemblage 4 to 5 metres above the base of the section. Numbers are small throughout the succession, apart from almost regularly spaced peaks of 5% to 10% of the total assemblage occurring every 6 to 8 metres.

Within Zone B, the dominant part of the benthonic fauna is constituted largely by Gavelinella ammonoides, Globorotalites cushmani and increasingly Lingulogavelinella sp. A. The common members of the Lituolacea and Nodosariacea, although still abundant have been overshadowed by the increasing diversity within the Cassidulinacea, a trend which continues through the whole of the succession studied. This feature was also noted by Hart and Carter (1975, text-figure 6) with reference to information drawn from the initial findings of the Thames Barrier Site Investigation.

The "M. coranguinum tabular flint" (Rowe 1901) situated 4 metres above the macrofaunal zonal boundary illustrates an interesting preservational feature. This tabular flint has within it a thin impersistant layer of "chalk meal", which was collected and examined as a comparison with the chalk immediately below the flint. The "meal" yielded a spectacular planktonic fauna which amounted to over 70% of the total foraminiferal population. In direct comparison, the planktonic fauna from the chalk immediately below the flint totalled less than 3.5% of the foraminiferal assemblage.

The effect of preferential preservation in silica is immediately suggested and discussed fully in Appendix A, with reference to additional information from other localities.

The "chalk meal" also contained Globotruncana concavata, a species only recorded previously from southern England by Barr (1962). In the present study it was only encountered in two other samples of soft chalk, one from Quidhampton, Wiltshire, and the other from Kelveden, Essex. The use of this species as part of a world-wide foraminiferal zonation (van Hinte 1976) is important when attempting to correlate this succession within such a scheme.

Immediately above the flint Stensioina exsculpta exsculpta appears for the first time, and the abundance of the planktonic fauna returns to its' "normal" low level. The correlation between the Langdon Stairs and St. Margarets' Bay sections is based on the appearance of S. exsculpta exsculpta and 5 metres higher, the first record of Loxostomum eleyi. This latter species, together with the first occurence of Vaginulinopsis scalariformis mark the base of Assemblage Zone C.

A relatively high proportion of planktonic foraminifera are also encountered at this level, including Globigerinelloides ehrenbergi for the first time together with Globotruncana primitiva, a species described originally from the Santonian of Tunisia (Dalbiez 1955). The similarities in the planktonic faunas found at the top of the St. Margarets' Bay section and at the base of the Hope Point section provide the basis for a tentative correlation between the two. They are also lithologically similar, as two distinct marl seams separated by a horizon of bioturbated marly chalk are present in both.

The benthonic fauna throughout the Hope Point section is again largely formed by Gavelinella ammonoides, Globorotalites cushmani, Gyroidinoides nitidus, Lingulogavelinella sp. A. , Lenticulina rotulata and Arenobulimina obliqua. Lingulogavelinella sp. A. is a consistant member of the fauna at this level and is beginning to increase in abundance. The other important members of the Cassidulinacea, Stensioina granulata, S. exsculpta exsculpta, Gavelinella thalmanni and Osangularia whitei var. whitei are present, although not common.

Towards the top of the Hope Point section Praebulimina reussi is recorded for the first time, providing a very useful microfaunal marker between this section and that of Oldstairs Bay. The presence of "Bedwell's columnar flint band" at the top of both these sections provides a good lithological correlation.

In the middle of the 6 metre Oldstairs Bay section a further faunal change is recorded, marked by the first appearances of Cibicides beaumontianus, Stensioina granulata var. A. and Eouvigerina sp. C. This break is used to mark the junction between Assemblage Zones C and D. It is also present in the Joss Bay section of the Isle of Thanet, and again it occurs 3 metres below the "columnar flint band".

Assemblage Zone D spans the section as high as "Whitaker's 3" band", which provides a useful lithological marker for the upper limit of the zone. The junction between Assemblage Zones D and E is marked by a number of microfaunal changes, not least of which is the extinction of Lingulogavelinella sp. A.

Throughout Assemblage Zone D this species becomes an increasingly abundant member of the population, occasionally totalling over 30% of the fauna. At the zonal boundary its disappears abruptly, apart from very rare specimens found above.

Cibicides ribbingi, C. beaumontianus var. A and Eponides cf. concinna all appear for the first fine at this level., together with rare specimens of Pyramidina cf. buliminoides. They are followed by the reappearance of Reussella kelleri in the 250 µ - 500 µ fraction. This species is again a consistant member of the fauna from this level.

This assemblage is considerably more diverse than that encountered at the bottom of the Langdon Stairs sections. It has been recorded to 3 metres above the "Barrois'Sponge Bed", where this section was terminated.

The following thicknesses were recorded for the assemblage zones in south east Kent:-

Assemblage Zone A - at least 22.20 metres

Assemblage Zone B - 17.00 metres

Assemblage Zone C - 28.20 metres

Assemblage Zone D - 14.30 metres

Assemblage Zone E - at least 11.70 metres

A correlation of the seven south east Kent sections is given in Enclosure 2.

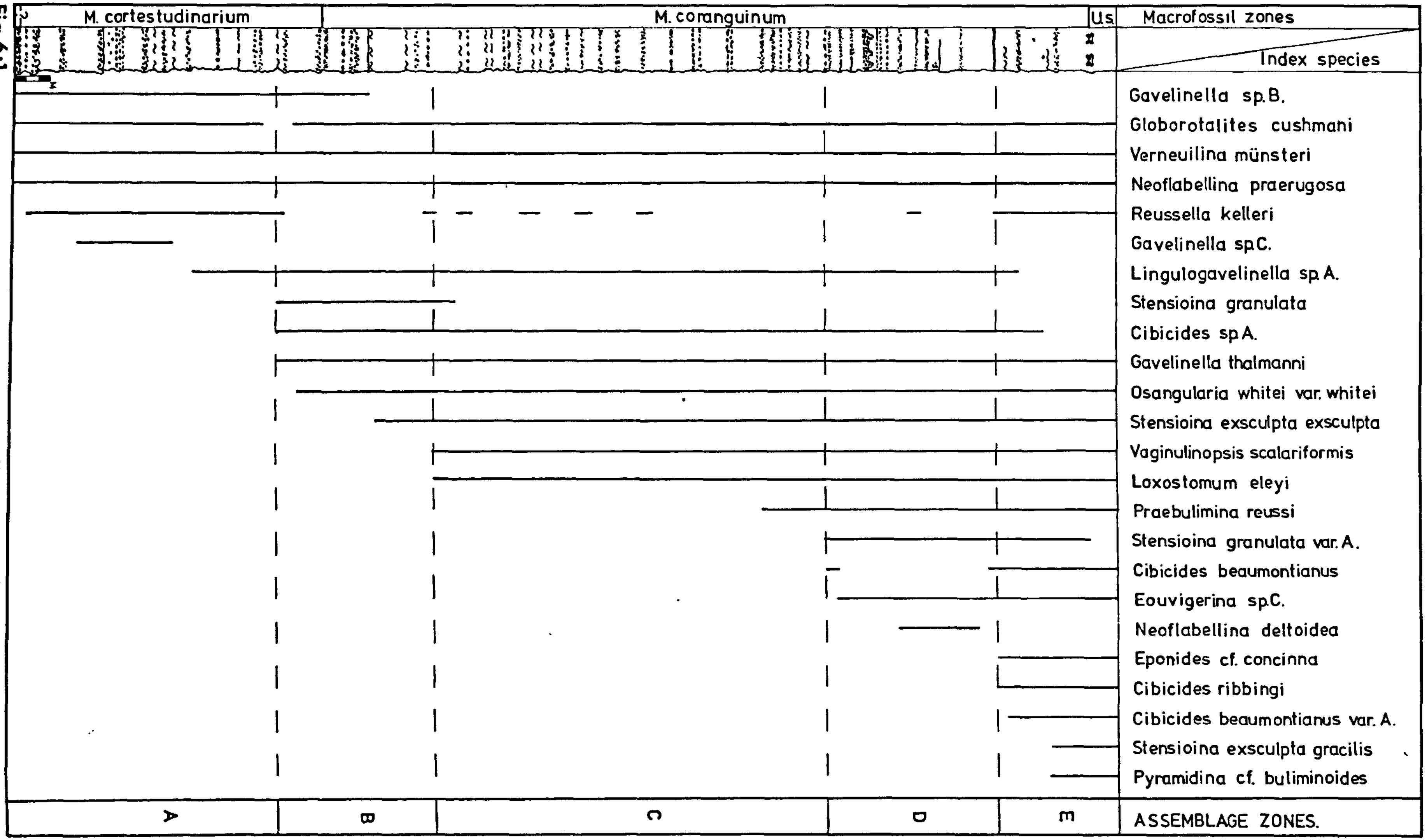


Fig.6:1

Zonation of the south east Kent section

6:2 Thames Barrier Site Investigation Boreholes, Woolwich.

The samples examined from the three boreholes were processed by Foundation Engineering Ltd., and core descriptions were made by D.J. Carter and M.B. Hart. The depths below surface level at which the samples were taken are given as reference points in the following discussion.

The lowest sample of Borehole No. 25 was taken at 97.12 metres, and the uppermost chalk sample was examined from 16.30 metres, although at this level the material was probably soliflucted, with a high content of sand, caving from the over burden. The section is extended a further 5 metres by the addition of the upper part of Borehole No. 19.

From the base of the section, for over 20 metres, the foraminiferal fauna contains a rich planktonic population, including *Globotruncana marginata*, *G. pseudolinneiana*, *G. bulloides* and *Hedbergella brittonensis*. These species total approximately 25% to 30% of the fauna, which is in contrast to the distinct lack of planktonic species higher in the section. Above 76.00 metres planktonic foraminifera become increasingly rare.

The benthonic population is dominated by *Lenticulina rotulata*, together with *Arenobulimina obliqua*, *Marssonella oxycona*, *Verneuilina münsteri*, *Tritaxia tricarinata* and *Gaudryina frankei*. *Reussella kelleri* is relatively common, together with *Gavelinella ammonoides*, *Gavelinella* sp. B. and *Gyroidinoides nitidus*. *Lingulogavelinella* sp. A appears at 87.00 metres, which suggests an earlier appearance in this section than that recorded in south-east Kent.

The top of Assemblage Zone A is again marked by the appearance of Stensioina granulata, Gavelinella thalmanni, Osangularia whitei var. whitei and Cibicides sp. A as in south east Kent. Reussella kelleri is only found in the fine sieve fraction above this level, until its reappearance in the 250 μ size fraction at the base of Assemblage Zone E. The base of Assemblage Zone B is taken at 58.80 metres below surface. Marssonella oxycona and Verneuilina münsteri are particularly common at this level.

Stensioina exsculpta exsculpta is recorded for the first time 8 metres higher mid-way through Assemblage Zone B. The appearence of the important species Loxostomum eleyi and Vaginulinopsis scalariformis, marking the base of Assemblage Zone C, occurs at approximately 43.00 metres. This zone is dominated by Arenobulimina obliqua, Gavelinella ammonoides and Lingulogavelinella sp. A., the latter increasing in abundance, as noted elsewhere, in this part of the succession.

The base of Assemblage Zone D is taken at 26.00 metres below surface, as both Praebulimina reussi and Stensioina granulata var. A. appear at that level. The species Cibicides beaumontianus and Eouvigerina sp. C., which are found in this zone on the Kent coast, do not occur at this locality until the base of Assemblage Zone E.

At 19.00 metres Lingulogavelinella sp. A. disappears abruptly from the assemblage. This feature provides a very useful marker for the correlation of Borehole No. 25 and Borehole No. 19.

Above this level, in Borehole No. 19, Reussella kelleri occurs in the 250 μ size fraction in association with Cibicides beaumontianus. Cibicides ribbingi is encountered 3 metres higher and this is characteristically followed by C. beaumontianus var. A. Throughout this upper part of the section, intermediate forms between S. exsculpta exsculpta and S. exsculpta gracilis are common. All the above species are considered to be typical of Assemblage Zone E.

The top of the section is taken at 4.91 metres below surface in Borehole No. 19, the material above this being soliflucted. Zonal thicknesses in the Borehole No. 25/Borehole No. 19 section are as follows:-

Assemblage Zone A - at least 37.4 metres

Assemblage Zone B - 14.5 metres

Assemblage Zone C - 16.5 metres

Assemblage Zone D - 12.2 metres

Assemblage Zone E - at least 6.4 metres

The thickness of Zone A is considered to be excessive, and it is thought probable that the borehole penetrated the upper part of the Holaster planus Zone, (a unit which was not thoroughly examined elsewhere). As the fauna at this level is somewhat restricted, no attempts to subdivide it have been made. It has subsequently been included in the lowest assemblage zone.

The section examined from Borehole No. 52, between 85.25 metres and 65.0 metres below surface, is included here as a comparison with the above account.

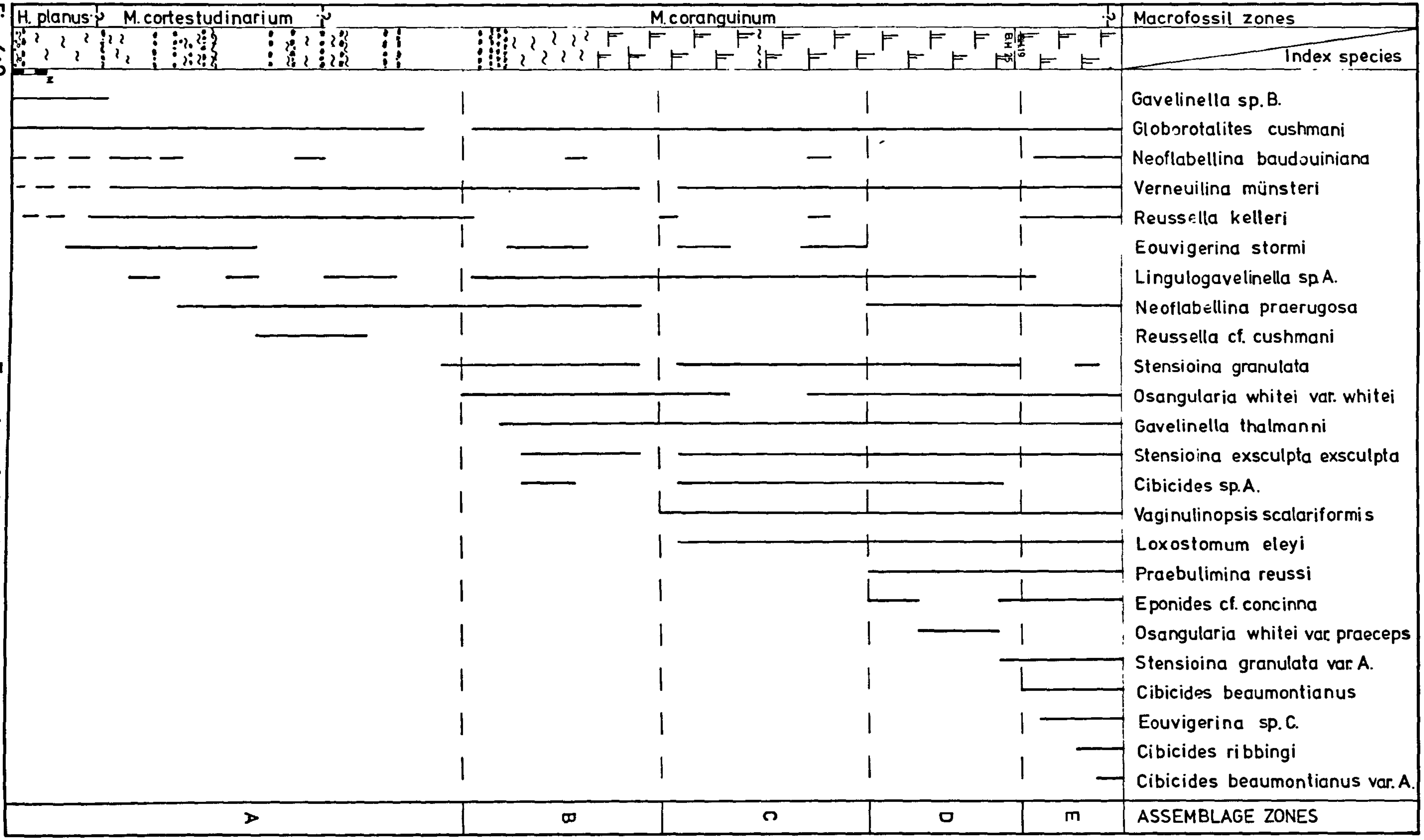


Fig. 6:2 Zonation of the Thames Barrier Site Investigation

The fauna, as expected, is extremely similar to that of Borehole No. 25, and the lower samples are characterised by the association of Lenticulina rotulata, Gavelinella ammonoides, G. pertusa, with Reussella kelleri, Lingulogavelinella sp. A. and Verneuilina münsteri.

The faunal break associated with the base of Assemblage Zone B falls at approximately 77.00 metres, as at this level Reussella kelleri disappears from the 250 μ size fraction and Stensioina granulata is noted for the first time. It is followed within the next 2 metres by Osangularia whitei var. whitei and Gavelinella thalmanni, Cibicides sp. A. normally found at this level, was not recorded in this section.

The rich planktonic fauna of this zone includes rare Globotruncana renzi, in addition to the more common G. pseudolinneiana, G. marginata, Whiteinella baltica, Hedbergella brittonensis and Heterohelix globulosa. Globotruncana bulloides is present, but is only abundant above 68.00 metres.

Stensioina exsculpta exsculpta occurs above 70.30 metres, followed 3 metres higher by Vaginulinopsis scalariformis and Loxostomum eleyi. This places the boundary between Assemblage Zones B and C at 67.00 metres. This section was terminated 2 metres higher, by which level Lingulogavelinella sp. A. has begun to increase in abundance.

The zonal thicknesses of this section are as follows:-

Assemblage Zone A - at least 8.25 metres.

Assemblage Zone B - 10.00 metres.

Assemblage Zone C - at least 2.00 metres.

As all the Assemblage Zones A to E are recognisable in the above borehole sections it is possible to correlate them with the published macrofaunal zones. Using the Langdon Stairs section as a comparison the junction of the two *Micraster* zones has been placed 2 metres above the boundary of Assemblage Zones A and B.

If the *M. cortestudinarium* Zone is accepted as being approximately 25 metres thick, as it is in Kent, then the lowest 12 metres of Borehole No. 25 represents part of the *Holaster planus* Zone. Subsequently the thickness of the *M. coranguinum* Zone at Woolwich would be approximately 50 metres. This is a reduction of 14 metres when compared with the zonal thickness seen in south east Kent. The thickness of Assemblage Zone C also appears to be relatively reduced in the Woolwich area.

6:3 The Isle of Wight

The two sections, Freshwater Bay and Culver Cliff, are considered separately. Assemblage Zones A to E are present in the former, whereas only Zones D to F were examined in detail at Culver.

The base of the Freshwater Bay section was located at the western extremity of the bay, using Rowe's (1908) description to locate the junction of the *H. planus* and *M. cortestudinarium* Zones.

This boundary is marked by two distinct marl seams, the upper of which was used as the base of the present measured section. The chalk below this level is inaccesible at this locality.

The whole of the M. cortestudinarium Zone and the lowest 5 metres of the M. coranguinum Zone form Assemblage A, characterised as usual by the abundance of arenaceous foraminifera and L. rotulata. Other common species (G. ammonoides, G. cushmani and G. nitidus, and the sporadic occurences of V. münsteri and R. kelleri) act as useful zonal markers.

Planktonic species are common, forming up to 20% of the fauna, although numbers are variable, possibly due to the variation in hardness of the chalk. The level of processing required varies accordingly, and may result in the destruction of fragile planktonic species at more indurated horizons. Hedbergella spp., G. marginata and G. pseudolinneiana dominate the planktonic fauna, together with some rare occurences of G. cf. angusticarinata mid-way through the zone.

Lingulogavelinella sp. A appears sporadically in the upper part of the zone, which equates, approximately, with the lower part of the M. coranguinum Zone. This species becomes more persistant towards the top of the Assemblage Zone, which is drawn at the first appearance of O. whitei var whitei, (as S. granulata was not encountered in this section). The other two characteristic markers for the base of Zone B, Cibicides sp. A and G. thalmanni, both occur within 3 metres of the zonal boundary. The addition of S. exsculpta exsculpta to the assemblage in the upper part of the zone correlates well with both the sections of south east Kent, and Woolwich.

The percentage of planktonic Foraminifera shows a gradual decrease throughout the zone, similar to that noted at the same level in the Thames Barrier Site Investigation sections. G. bulloides is added to the species list of the underlying zone together with W. baltica, which occurs from the base of Zone B. Nine metres above this boundary there is an horizon dominated by planktonic Foraminifera, including rarer species such as G. renzi, G. cf. angusticarinata and G. primitiva. All of these are consistant with a mid to late Coniacian age for this part of the succession.

The decline of the planktonic fauna towards the top of Zone B provides a useful marker for the correlation of the eastern and western sides of the bay. A few metres above the base of the eastern section the appearance of L. eleyi, together with occasional specimens of V. scalariformis, marks the base of Assemblage Zone C.

Lingulogavelinella sp. A increases in abundance throughout this zone until it totals over 30% of the foraminiferal fauna. Gavelinella spp. are also extremely abundant. P. reussi, although present in this section, never becomes as common as it is at other localities. Because of this, and the absence of S. granulata var. A it is difficult to determine the upper boundary of the zone. However, the extinction of E. stormi may be used as an alternative marker, as it occurs consistantly at this level elsewhere. This species has a limited stratigraphic value as it is not common and is represented only as very small individuals.

Four metres above the junction of Zones C and D Eouvigerina sp. C is recorded for the first time, followed by Eponides cf. concinna, which equates with the standard zonation. The extinction of Lingulogavelinella sp. A mid-way through Zone D is more unusual as it normally marks the upper limit of the zone. This boundary was based however on the distinctive appearance of the group of species including C. beaumontianus, C. ribbingi, followed by C. beaumontianus var. A. These, together with large numbers of R. kelleri and early forms of S. exsculpta gracilis are all characteristic of Assemblage Zone E. It is also worth recording that O. whitei var. whitei is common in this zone in the Freshwater Bay section.

The hardness of the chalk, resulting from the structural deformation which this area has undergone, makes processing difficult. This in turn often results in apparently poor faunas, with stratigraphically important species often rare or absent. However, it is still possible, despite these difficulties, to erect a viable zonation, with thicknesses of:-

Assemblage Zone A - at least 22 metres.

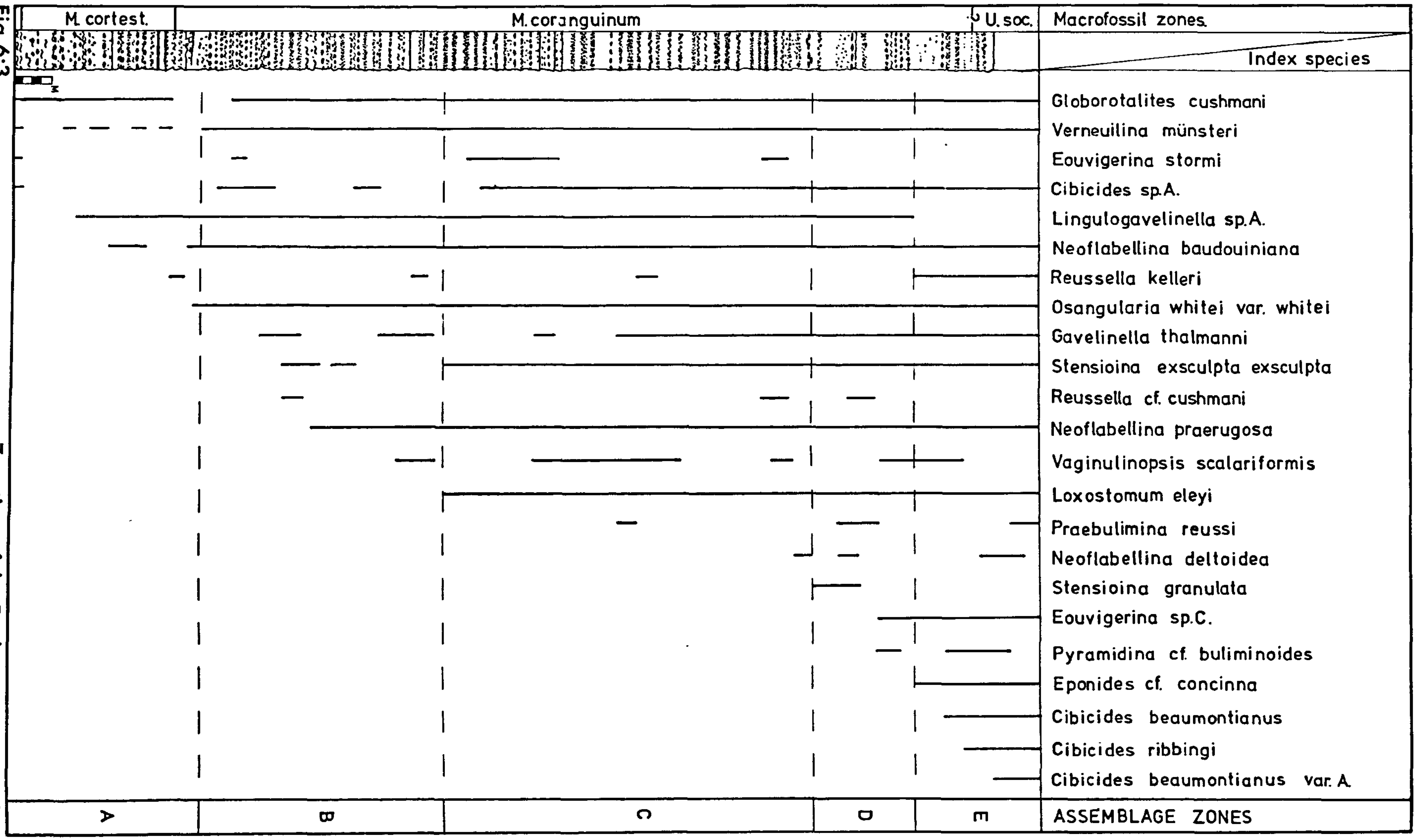
Assemblage Zone B - 29 metres.

Assemblage Zone C - 33.2 metres.

Assemblage Zone D - 14.5 metres.

Assemblage Zone E - at least 12.4 metres.

Fig. 6:3



Zonation of the Freshwater Bay section, Isle of Wight

Culver Cliff.

The accessible part of the M. cortestudinarium Zone and the whole of the M. coranguinum Zone (Rowe 1908), were collected, although on the strata which Rowe considered to be the uppermost 75 metres of the M. coranguinum Zone were examined in detail. The results of this work led to the recognition of a foraminiferal zonation for the section, which has brought Rowe's macrofaunal boundaries into question.

There has always been doubt as to the position of the upper limit of the M. coranguinum Zone, since Rowe (op. cit) recorded that "we have no chance of obtaining any definite measurement, by reason of the fact that a fresh fall has occured in the little bay on the north side of the White Horse". He also commented that "This fall has caused the chalk on either side of it to be so obscured by dust that the section in the area is quite unworkable".

Rowe (op. cit.) estimated that approximately 300 feet (91.5m) of chalk belonging to the M. coranguinum Zone was exposed at Culver Cliff. This figure was later reduced by 26½ feet by Brydone (1914) in his detailed examination of the overlying U. socialis Zone. It is also noted that there is some confusion as to the thickness of the Marsupites testudinarius Zone (Barr 1962), and a detailed re-study of the macrofauna of this important section is necessary.

The present work, as stated previously, is restricted to the results of the construction of a microfaunal zonation. Macrofossils were always recorded in the field, but sufficient time was not available for a more complete revision of the section.

The uppermost samples were thought to include the basal junction of the U. socialis Zone, thus a microfaunal correlation should have been possible with Freshwater Bay. When the foraminiferal assemblage at this horizon was examined, it was found to include species totally different to those found at this level elsewhere. These included Gavelinella sp. C. , G. cf. clementiana, R. szajnochae var. praecursor, Q. trochoides and Cassidella sp. A. along with later forms of S. exsculpta gracilis than those encountered in other sections. Other species, such as P. cf. buliminoides, C. ribbingi and C. beaumontianus var. A. which are present at the highest levels in other sections were quite common. This assemblage suggested that the chalk of the M. coranguinum - U. socialis Zonal junction, (Rowe 1908) of Culver Cliff is, in reality, stratigraphically younger than the same level elsewhere.

The examination of the foraminifera 45 metres lower in the section established the junction of Assemblage Zones D and E, based on the extinction of Lingulogavelinella sp. A and the first occurrences of C. beaumontianus and E. cf. concinna. The upper limit of Assemblage Zone E was based on the first appearance of R. szajnochae var. praecursor and Gavelinella sp. C. the unit above this being referred to as Assemblage Zone F.

Lower in the section all the usual stratigraphic markers are present, including R. kelleri, S. granulata, S. granulata var. A. P. reussi and S. exsculpta exsculpta. The combination of Lingulogavelinella sp. A. G. thalmanni, O. whitei var whitei and Cibicides sp. A in the region of the M. cortestudinarium - M. coranguinum Zonal boundary (Rowe 1908) suggests that the base of Assemblage Zone C is close to this level.

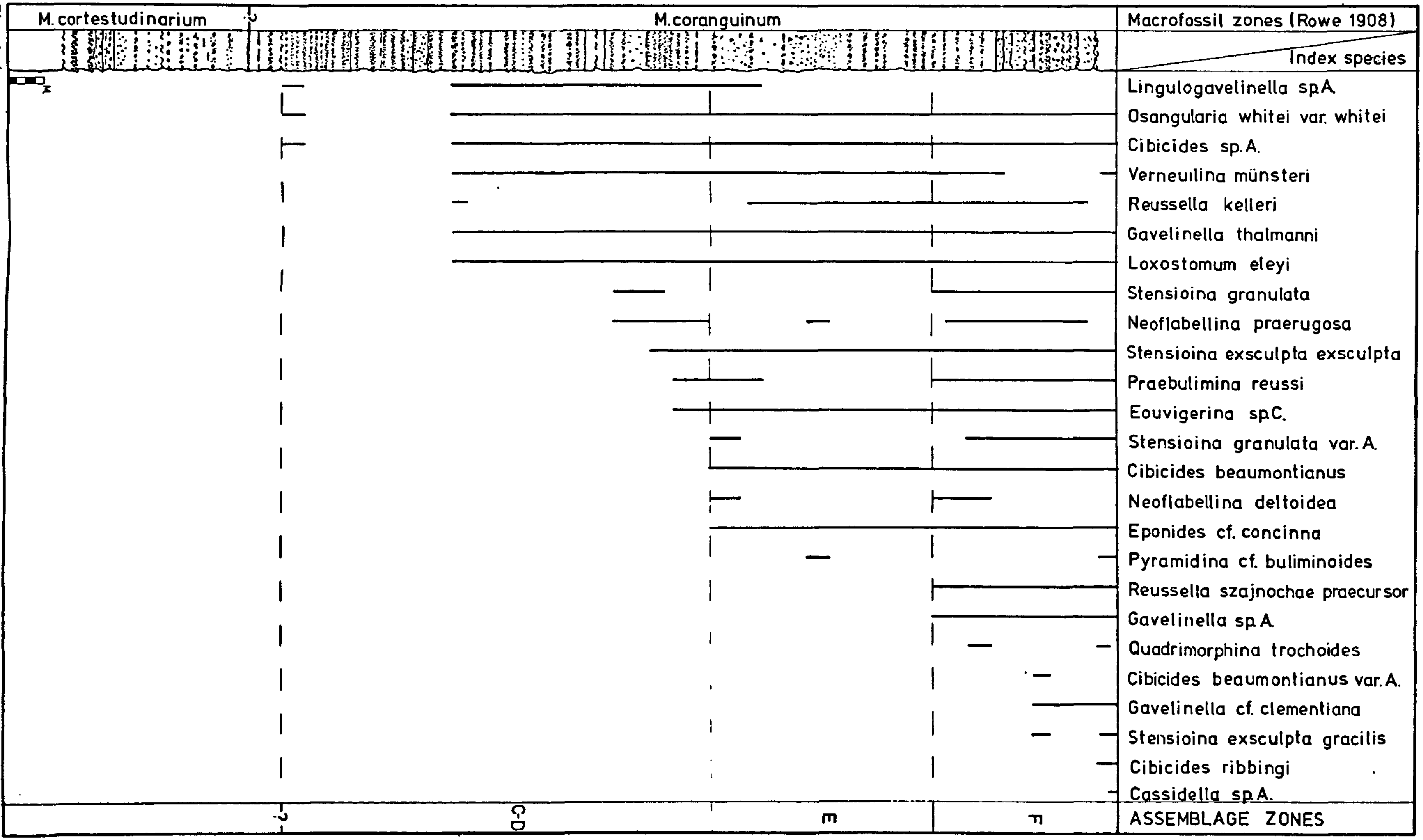


Fig.6.4

Zonation of the Culver Cliff section, Isle of Wight

This, when compared with other localities, also indicates that Rowe's (op. cit.) assessment of the lower macrofaunal zones may be incorrect, although only a preliminary examination of the microfauna was carried out at this level.

To summarise, the upper limit of the M. coranguinum Zone falls approximately 12 metres above the junction of Assemblage Zones D and E at all the localities studied, except Culver Cliff where it occurs 35 metres higher. Even allowing for slight discrepancies in zonal thicknesses between sections, it would seem that Rowe's (1908) boundary between the M. coranguinum Zone and U. socialis Zone was placed at least 20 metres too high. This figure is considered to be an acceptable estimate for a poorly accessible section from which Rowe recorded a "meagre" macrofaunal list.

The thicknesses for the microfaunal Assemblage Zones recorded are as follows:-

Assemblage Zone D - at least 15 metres.

Assemblage Zone E - 18 metres.

Assemblage Zone F - at least 21.4 metres.

6:4 Norfolk

The use of the Micraster zones in Norfolk, as interpreted by Peake and Hancock (1961, p. 309), leads to the inclusion of chalk equivalent to the lowest third of the M. coranguinum Zone of southern England within the preceding M. cortestudinarium Zone. This is caused by the lack of stratigraphic markers and the poor macrofauna.

Fortunately, the microfauna is rich and diverse. Both the sections studied, Helhoughton and Newton-by-Castleacre (and also the material examined from Burnham Overy), yielded abundant foraminifera.

The first of these, Helhoughton, is recorded by Peake and Hancock (op. cit). as belonging entirely to the M. cortestudinarium Zone. However, on examination, the rich microfauna proved the section to lie across the junction of Assemblage Zones C and D. This horizon lies high within the M. coranguinum Zone when compared with the rest of southern England.

The lower half of the section is dominated by a large number of planktonic Foraminifera. G. bulloides is extremely abundant, totalling 33% of the fauna 2 metres from the base of the section. Other common species of the same genus are G. canaliculata and G. pseudolinneiana. The benthonic fauna includes Lingulogavelinella sp. A., S. granulata, R. kelleri, S. exsculpta exsculpta and L. eleyi, but it is not until the upper half of the section that these show a marked increase in abundance, particularly the first two species.

These are joined by P. reussi, V. scalariformis, Eouvigerina sp. C. and S. granulata var. A. in the upper half of the section. The latter two species are used as indicators for Assemblage Zone D. The planktonic fauna also shows an increased diversity, by the addition of A. bosquensis and G. ehrenbergi.

The correlation of this section with the rest of southern England is a simple procedure, as all the important marker species are present.

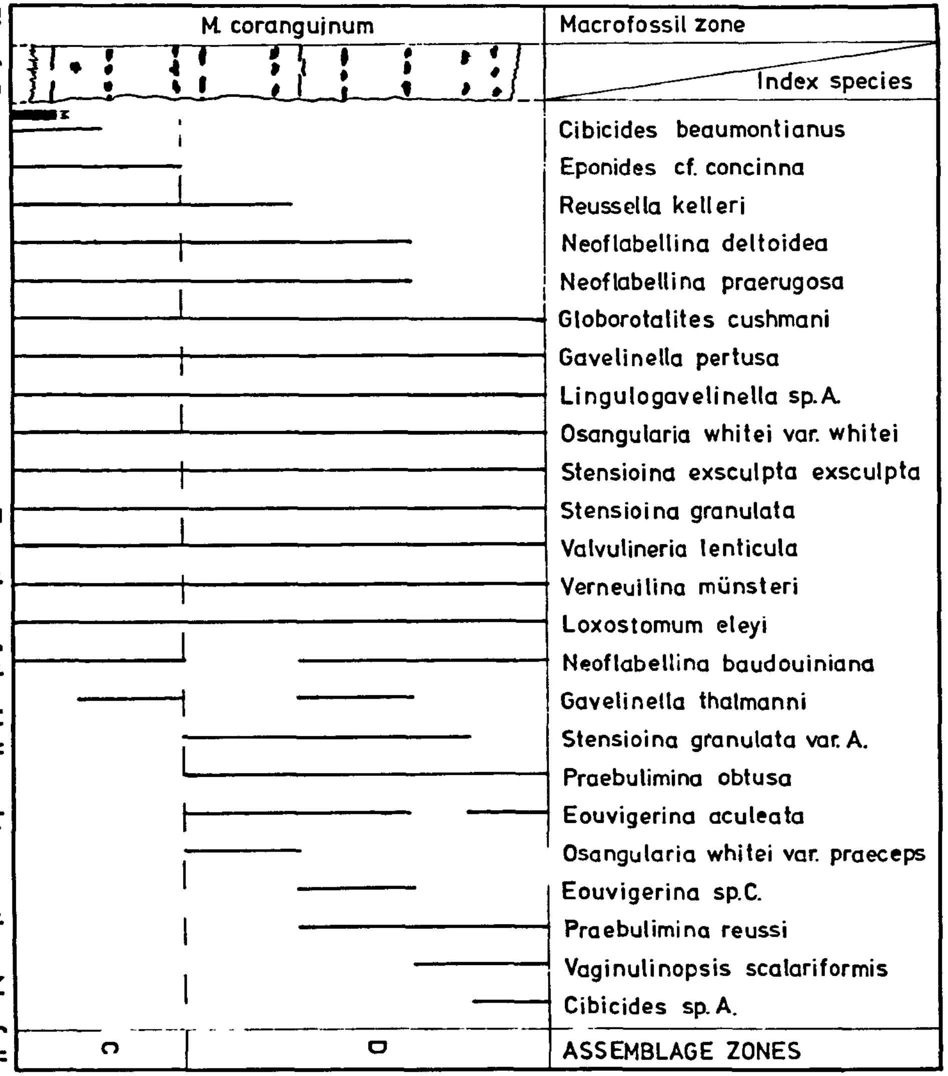


Fig. 6:5

Zonation of the Helhoughton section, Norfolk

The presence of the boundary between Zones C and D is important, as when this is compared with the south east Kent succession, it equates the present section with the chalk immediately below "Bedwell's columnar flint" band. This then places it at the base of the Santonian, as given by Casey et al (in press).

The section at Newton-by-Castleacre lies stratigraphically very close to that at Helhoughton. Peake and Hancock (op. cit.) regarded it as being higher in the succession, yielding material across the junction of the Micraster zones.

G. bulloides is again extremely abundant in the lower part of the section, although at this locality it is joined by large numbers of R. kelleri, which is normally rare at this level. S. granulata and S. exsculpta exsculpta are both present throughout the section, and the appearance of S. granulata var. A. and Eouvigerina sp. C in samples from the top of the section is reminiscent of the faunal change at Helhoughton.

The low number of Lingulogavelinella sp. A are normal for an horizon below Assemblage Zone D, and the rare occurrence of A. bosquensis is also similar to the situation at Helhoughton. G. rowei is present at Newton towards the base of the section, which is a further indicator of the stratigraphic level found in the section.

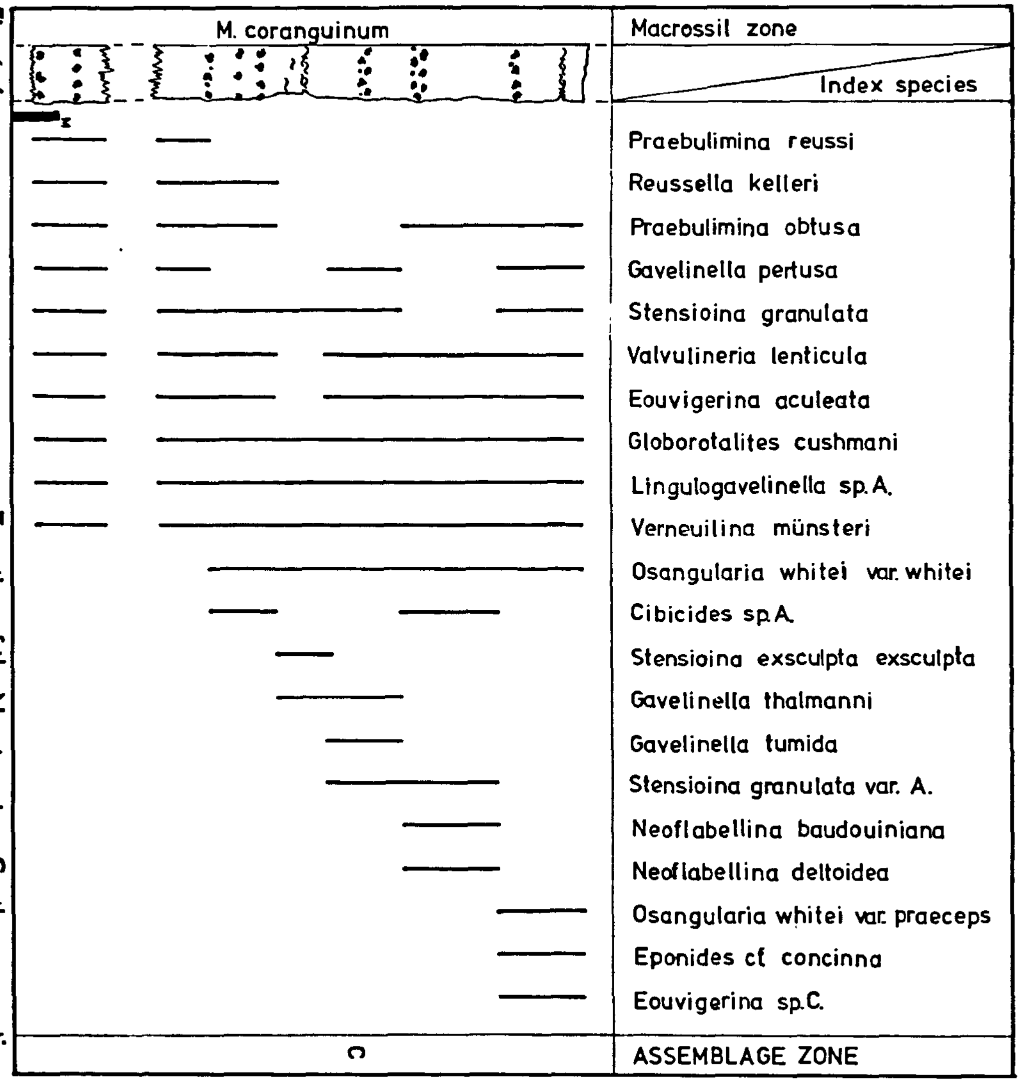


Fig. 6:6

Zonation of the Newton-by-Castleacre section, Norfolk

The material from Burnham Overy is believed to belong to Assemblage Zone D, as it yielded large numbers of S. granulata var. A. in addition to S. exsculpta exsculpta and O. whitei var. whitei.

Both the sections are relatively small, being less than 12 metres in thickness, and both are similar in the microfauna which they yield. It appears that they lie well within the established description of the M. coranguinum Zone, based on the foraminiferal assemblage, when correlated with the southern English coast, a point which is also true for Burnham Overy.

6:5 Quidhampton, Wiltshire.

The soft chalk at this locality yielded an exceptionally rich fauna, both in number and diversity. Sixteen arenaceous species were recorded, the more common being A. obliqua, A. variabile, V. münsteri, M. oxycona and E. gibbosa var. globulosa, together with thirty four species belonging to the Nodosariacea. These included V. scalariformis, Citharinella sp. A., N. deltoidea and N. praerugosa which are of limited stratigraphic value, the remainder being long-ranging species.

The section, for the most part, has been placed in Assemblage Zone D, the species of the Cassidulinacea and Buliminacea characteristic of this level, all being present. The top of the zone is taken at a level 22 metres from the base of the quarry. This is less than a metre above the uppermost flint horizon, a distinctive tabular band, described in the lithological discussion, Lingulogavelinella sp. A becomes extinct at this level and C. ribbingi, C. beaumontianus var. A and P. cf. buliminoides are added to the fauna.

It is thought that the junction of Assemblage Zones C and D occurs towards the base of the section, approximately 6 metres above the quarry floor. C. beaumontianus is recorded for the first time at this level, followed closely by S. granulata var. A. Eouvigerina sp. C, which is normally only found above the base of Assemblage Zone D is present throughout the section, suggesting that the boundary might be lower.

The planktonic fauna from this locality is relatively few in numbers, but very diverse, with G. concavata, G. linneiana, G. rowei, G. ehrenbergi and a late G. renzi in addition to the common species G. pseudolinneiana, G. marginata, H. brittonensis, W. baltica and H. globulosa.

The microfauna of this section relates well to that of south east Kent, and it is interesting to note that the junction of Zones D and E occurs in close proximity to the last major flint band in both sections. The foraminiferal zonation agrees with the placing of this section in the uppermost part of the M. coranguinum Zone (Jukes - Brown and Hill 1904), presenting a good example of the relationship between the macro- and microfaunal zones.

The zonal thicknesses at this locality are as follows:-

Assemblage Zone E - at least 5 metres.

Assemblage Zone D - approximately 16.5 metres.

Assemblage Zone C - at least 6.5 metres.

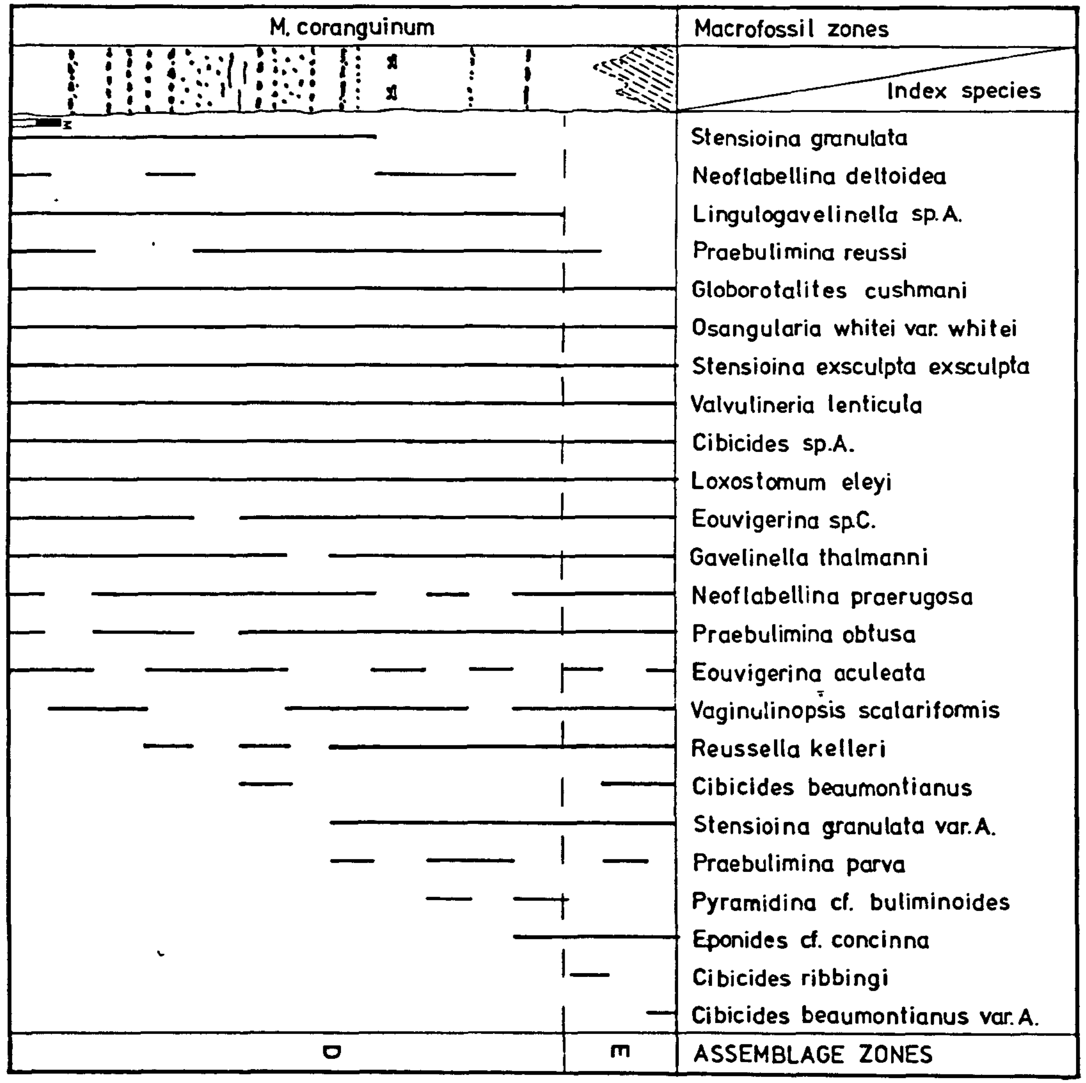


Fig. 6:7 Zonation of the Quidhampton section, Wiltshire

6;6 Beer, South east Devon.

In the past there has been some discussion as to the exact position of the lower limit of the M. cortestudinarium Zone at this locality (Rowe 1903, Jukes -Browne and Hill 1904). It was generally agreed however, that it fell within the section at Annis' Knob. Jukes - Browne and Hill (op. cit.) used the distinct "tabular" flint band, mid-way up the cliff face as a lithostratigraphic marker for the zonal boundary. Its' use is noted here as a guide to the distinct change in the foraminiferal assemblage.

The microfauna is not particularly abundant, especially at those indurated levels above the flint. The presence of several phosphatised incipient hardgrounds in the section (Kennedy & Garrison, 1975) meant that thin sections had to be examined at several horizons, in the absence of material prepared by normal processing.

The role of the planktonic fauna in acting as a guide to the base of the lower Senonian has been described by Bailey (1975). The lower part of the section is dominated by the species G. pseudolinneiana, used by Owen (1970) in defining the uppermost foraminiferal subzone for the Turonian. Approximately one metre above the distinct tabular flint this species is replaced in importance by G. marginata and early forms of G. bulloides.

G. renzi was recorded three metres higher and noted as being an index species for the Coniacian. The species however may be found in the uppermost Turonian and is used merely to substantiate the faunal break marked by the other species, at the stage boundary.

The section is believed to lie entirely within Assemblage Zone A, as none of the later stratigraphic markers are recorded. V. münsteri appears in the lower part of the cliff, and R. kelleri is noted a few metres higher. Both of these are used to define the base of the Coniacian in northern France (Robaszynski, in Colbeaux et al 1975) and it is believed that their first appearance in this succession is indicative of the same stratigraphic horizon. Gavelinella sp. B. is also common in this section equating, with its' presence at the base of the Langdon Stair section at Dover.

Other common species include G. ammonoides with some possible specimens of Gavelinella sp. C. A. obliqua, M. oxycona and A. variabile are abundant, often totalling over 50% of the fauna. L. rotulata is common, along with fifteen other species of the Nodosariacea including N. praerugosa, G. trigonula, L. ovalis and numerous Nodosaria sp. A.

The section is in total 17 metres thick, and regarded as being typical of the lower part of Assemblage Zone A. The base of the section is believed to be Turonian and therefore below the present zonation.

6:7 Arish Mell Dorset.

The thin sections made from samples collected at Arish Mell yielded examples of G. bulloides, G. pseudolinneiana and G. cushmani (see Plate 15.2), along with L. rotulata and several arenaceous species. These fail to provide any definite evidence for the precise age of the section, although they suggest that it lies within the Coniacian.

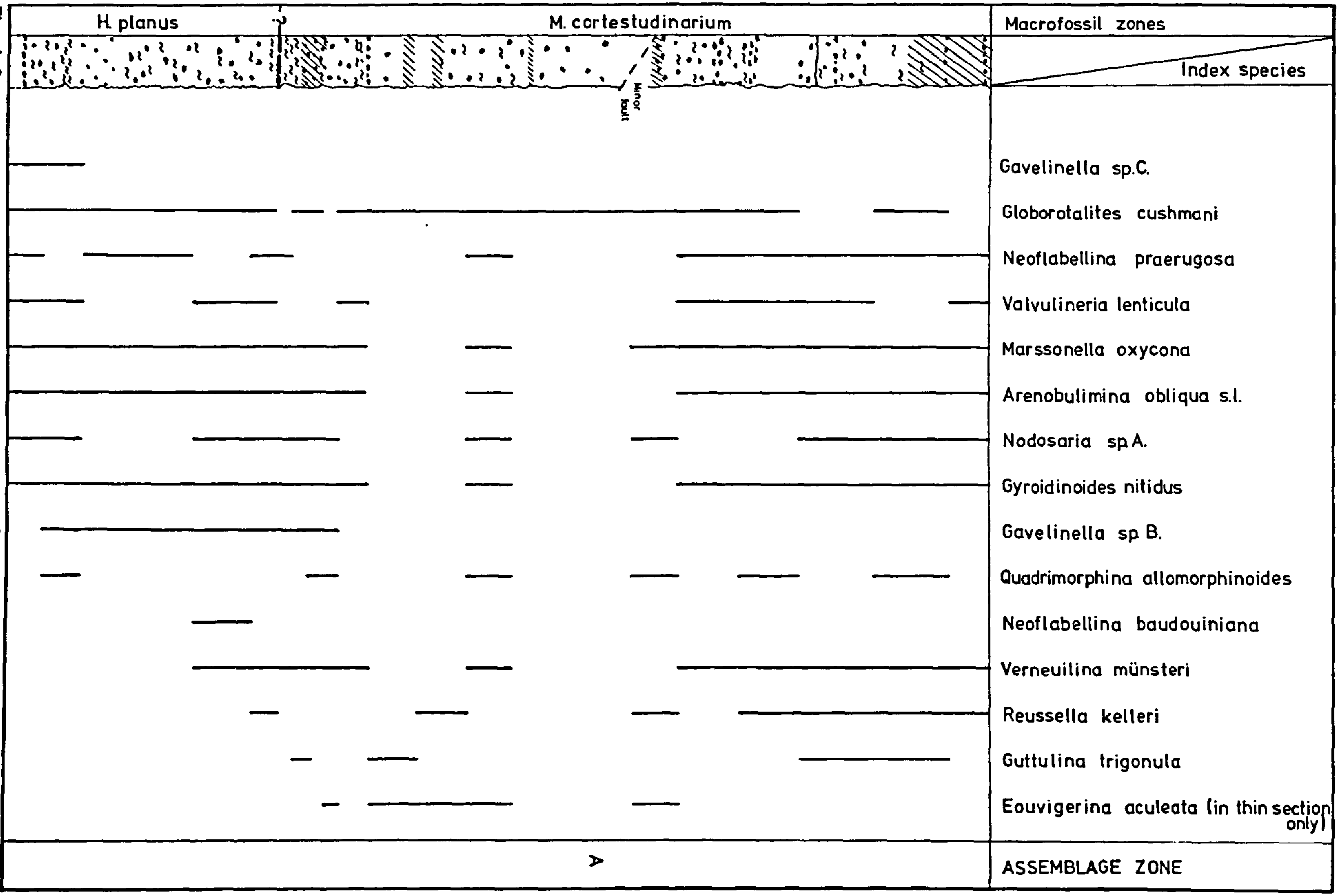


Fig. 6:8 Zonation of the Beer section, south east Devon

6:8 Borehole samples, Essex.

During the course of this study two borehole samples obtained by the Institute of Geological Sciences were examined. Both the boreholes were primarily intended as studies of Tertiary strata, in the revision of the 1 inch Geological Sheet No. 241 (Chelmsford District), and they were terminated once they had penetrated a short section of bedded chalk.

The holes were drilled at Witham (Grid ref. TL 8244 1534) and Kelveden (Grid. ref. TL 86021797), Essex, and the initial results were published by the I. G. S. in their Annual report for 1971. This assigned both samples to the U. socialis Zone. The Witham sample was taken at a depth of 87.22 - 87.45 metres below surface, from a 3.61 metre core of chalk. The Kelveden core yielded 2.09 metres of chalk with flint from a depth between 79.04 and 82.30 metres below surface.

Foraminifera were extremely abundant in both samples and the faunal diversity was high, including numerous species of stratigraphic importance. G. bulloides, G. linneiana and G. canaliculata were common, and a specimen of G. concavata was noted in the material from Kelveden, giving it a Santonian age. The more important benthonic species present in both samples are listed below. They have been combined as the faunas were effectively the same.

S. granulata var. A.

S. exsculpta exsculpta.

S. exsculpta gracilis *

G. cf. clementiana *

O. whitei var. praeceps *

P. reussi

P. cf. buliminoides *

R. kelleri

R. szajnochae praecursor *

C. beaumontianus

C. beaumontianus var. A.

C. ribbingi

All these species are typical of the highest part of the succession examined in this study, particularly those marked with an asterisk, which are characteristic of Assemblage Zone F. This zone is believed to equate approximately with the base of the U. socialis Zone, confirming the original placing of the chalk at the correct stratigraphic level. An early to mid-Santonian age is suggested by the planktonic fauna.

6;9 The use of the proposed zonal scheme

The introduction of a zonal scheme for the lower Senonian of southern England must be of general application if it is to be of real value. Thus the correlation of numerous sections, based on such a zonation, provides both the evidence for the scheme and its' justification.

The proposed zonation, besides providing a broad description of the foraminiferal assemblage as a whole, and in particular those species of stratigraphic value, is also significant in several other respects which are discussed below:-

i) It allows a detailed analysis of the total faunal assemblage, primarily the foraminifera in the present study, within a defined unit. Thus variations in the relative proportions of taxa, from Superfamily to species, and the evolutionary trends present in these groups can be recorded within a predetermined framework.

ii) The microfaunal stratigraphy can be readily correlated and compared with the existing macrofossil zonation. It follows that where the macrofauna is sparse, microfossil studies may help to qualify and clarify the stratigraphy. This is proven by the application of the proposed scheme to the Culver Cliff section, where the present evidence suggests that the existing macrofaunal zonal boundaries may be wrongly positioned, when compared with other sections.

This application of the scheme is also of value in the correlation of long borehole sections, both with each other and with established exposures. This is the situation present in the correlation of the Thames Barrier Site Investigation boreholes with the succession seen on the coast of south east Kent.

iii) The above application may also be used in the evaluation of individual spot samples where the macrofauna is poor. This was carried out on the samples from Burnham Overy, Witham and Kelveden. In the case of the last two, the sub-Tertiary Chalk outcrop was dated and related to the existing macrofossil zones.

iv) By comparing the relative thicknesses of each of the proposed zones in the sections studied, some indication of differential rates of sedimentation may be observed. Table 1 gives the zonal thicknesses for the more important sections, arranged approximately west to east, and correspondingly with the greater thicknesses present to the west. This is certainly apparent in Zones B and C and less obviously so, in Zone D.

Zones	Freshwater Bay	Culver Cliff	Quidhampton	S.E. Kent	Thames Barrier
E	12. 4m	18.0m	6. 5m	11. 7m	6. 4m
D	14. 5m	15.0m	16. 5m	14. 3m	12. 2m
C	33. 2m		5m	28. 2m	16. 5m
B	29. 0m			17. 0m	14. 5m
A	22. 0m			22. 2m	37. 4m

Table 1.

The thicknesses of these zones are doubled in the Isle of Wight when compared with those of the Thames Barrier Site Investigation boreholes. The interpretation suggested is one of varying structural controls in the areas studied during the lower Senonian. To the east it is known that the London Platform, or East Anglian Massif (Kent 1975) was still a positive structural block during the Cretaceous, although this was probably due to the relative subsidence of the adjacent trough.

In the present study, the Wessex Basin provides the area with the greatest thickness of preserved Chalk deposits.

It seems unlikely that the suggested variations in zonal thickness is entirely due to differential compaction during diagenesis, as the Wessex area has certainly undergone greater tectonic stress than south eastern England. It would therefore appear that the sedimentary thicknesses of the foraminiferal zones are at least partially due to the primary rates of sedimentation.

It may be inferred from this that the old pre-Mesozoic structural regimes were still active during the Late Cretaceous, if only on a relatively minor scale. An interpretation which qualifies the outline summarised by Kent (1975) which stated that "the Chalk was widely transgressive and essentially unaffected by structural complications in the underlying rocks".

v) Finally, by using the characteristic members of the fauna, comparisons may be drawn with similar foraminiferal assemblages described from elsewhere. This has been carried out in detail in Chapter 7, using literature related to the important Upper Cretaceous outcrops of Northern Europe.

In this way the relationships of faunal assemblages can be deduced on an international basis, and comparison can be made with what is known of the foraminifera of the stratotype region of south western France. The validity of the Turonian-Coniacian and Coniacian - Santonian boundaries as suggested by Casey et al (in press) for southern England can be assessed.

CHAPTER 7.

FORAMINIFERAL CORRELATION IN THE EUROPEAN LOWER SENONIAN.

7:1 Introduction

The lower Senonian lasted for approximately six million years (van Hinte, 1976), and during this time the sedimentary history of northern Europe was one of relative stability. The conditions of chalk deposition have proved a subject for considerable discussion, and recent works by Kennedy and Garrison (1975) and Hancock (1976) have provided detailed reviews of current ideas.

These two publications have therefore furnished most of the information used in the present study, with respect to the environmental factors controlling sedimentation during the European Late Cretaceous.

7:2 Palaeogeographic features of northern Europe.

A major regressive event occured during the middle to late Turonian (Hancock 1976, Petters 1976), and the Coniacian to early Santonian represents a period of continuous, gradual, inundation following this event. The maximum transgressive phase was not reached until the late Campanian. This sequence of events can be seen in the succession in Northern Ireland (Hancock 1961) where the thin Turonian and lower Senonian are represented by glauconitic limestones and calcareous glauconitic sands. The calcium carbonate content increases progressively, true chalks being deposited in the upper Senonian.

The period was also one of increasing oceanic water temperature, a factor proposed by Urey et al (1951), Lowenstam and Epstein (1954), and Bowen (1961). Bandy (1967) interpreted this work in relation to planktonic foraminiferal evolution during the Upper Cretaceous, and this was reviewed by Hart and Carter (1975) in a discussion of Cretaceous foraminiferal research in this country.

As Hart and Carter (op. cit) point out, it seems probable that this rise in temperature is directly related to the increase in sea level. The resulting submergence of the land masses on the western margin of the European continental shelf (the Armorican, Cornubian, Hibernian and Caledonian massifs) allowing warmer oceanic currents to circulate further across the shelf area.

There is a growing body of data with regard to the oceanic current circulation of the North Atlantic, during the Middle to Late Cretaceous,(Banner 1972, Luyendyk et al 1972 Irving et al 1974). The model proposed by Luyendyk et al (op. cit.) for the mid-Cretaceous North Atlantic palaeogeography is employed, following it's discussion and modification by Hart and Carter (op. cit) and Hart (1976). By reducing the land areas on the Atlantic sea-board (Hart and Carter op. cit, t. fig. 10), the probable current directions can be postulated for the early Senonian. (Fig. 7:1). A non-glacial wind configuration is used, in the light of a suggested water temperature range between 20°C and 25°C (Urey et al 1951, Lowenstam and Epstein 1954 and Bowen 1961).

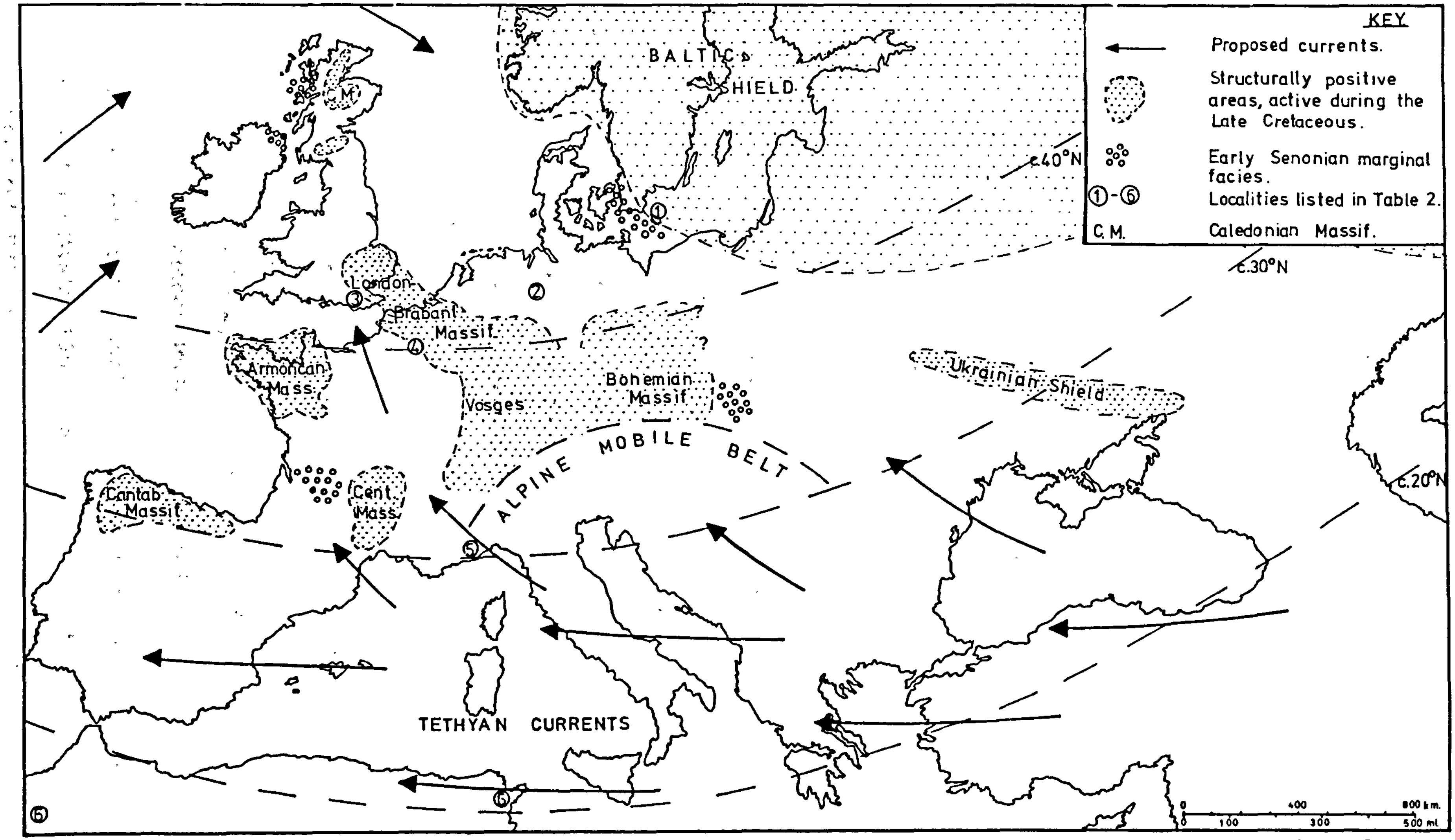


Fig. 7:1 Palaeogeographic features of the European lower Senonian

The direction of mass water movement through the Tethyan ocean was east to west, and Luyendyk et al suggest that a closed gyre system would have existed in the rapidly expanding North Atlantic. It is also likely that warmer bodies of water, in the form of northerly branches of the main Tethyan stream, would pass across Europe carrying more typically southern planktonic foraminifera with them. This direction of current flow was present during the Cenomanian (Hart 1976), and the occurrence of G. concavata and G. renzi in southern England indicates similar water movement during the Coniacian and Santonian.

These northerly currents would pass into the northern European province through the deeper channels of the Wessex - Paris Basin and the Danish - Polish Trough. The margins of these basins were formed by the positive areas of the Armorican and Central Massifs, the Central European (Bohemian) and the London-Brabant Massifs and the Baltic Shield (Fig. 7:1), which were partially, if not totally, submerged during the late Cretaceous transgression. The thinning of the lower Senonian succession between the Wessex Basin and the London massif has already been discussed in Chapter 6.

Evidence for the margins of the Chalk Sea in the European province is scarce and in the British Islesin particular it is restricted to the scattered sandy chalk deposits of the Western Isles of Scotland (Bailey 1924, Lee and Bailey 1925) and the Hibernian Greensands of Northern Ireland (McGugan 1957).

In contrast, the typical white chalk of the Ballydeenlea deposits in Eire (Walsh 1960, Barr 1966) indicate the presence of the "normal" chalk facies to the west of the English outcrop.

The chalk of south-east Devon was deposited on the edge of the Wessex Basin, and the succession of phosphatised hardgrounds and incipient hardgrounds (Kennedy and Garrison 1975) suggests a relatively shallow depth of deposition.

The Senonian stratotype region of northern Aquitaine, situated on the north western flank of the Central Massif, is another area of marginal deposition (Séronie-Vivien, 1972). The Coniacian and Santonian deposits of this region comprise glauconitic, calcareous sands and bioclastic gravels. It was not until the maximum transgressive phase of the Campanian that the water depth was great enough to result in white chalk deposition. By the early Maastrichtian a more terrigenous facies had been re-established.

A similar sedimentary sequence is present to the north of the Bohemian massif, the Cretaceous palaeogeography of the area being recently described by Diener (1967). Further to the south east, in northern Bohemian and Saxony, a sedimentological study of Turonian – Coniacian cross-bedded sands (Jerzykiewicz 1967) has suggested that the detrital material was derived from small islands of crystalline basement to the north and north east. These would have lain to the north of the main Bohemian massif illustrated by Hancock (1976), and a narrow sedimentary trough was present between the two.

The north eastern edge of the lower Senonian Chalk Sea was formed by the Baltic Shield, and between this and the Danish – Polish Trough there are several descriptions of marginal deposits.

Brotzen (1945) described the marly conglomerates of Ystad-Vomb in southern Sweden, and Bergström et al (1973) have produced a detailed analysis of the calcareous sands and conglomerates of the Sardal district. The description of the planktonic foraminiferal fauna of the Bavnodde Greensand (Douglas and Rankin 1969), from the Island of Bornholm is also important as it provides a useful palaeogeographic discussion.

Apart from these areas, northern Europe was submerged beneath the Chalk sea and a unified environment of deposition covered the whole area.

Two other regions, further to the south, have been considered in this discussion, simply due to the existance of detailed micro-faunal studies. The Upper Cretaceous foraminiferal succession of the Mangyshlak Peninsula, on the eastern shore of the Caspian Sea, has been fully described by Vasilenko (1961), and here again the lower Senonian is represented by marls and chalks. More recently, Porthault (1974) has produced a major study of the Upper Cretaceous stratigraphy of the "Fosse Vocontienne" region of south eastern France. Both are extremely useful, the latter in particular, as they provide the faunal links between the northern European province and Tethys.

7:3 Comparison of European lower Senonian Foraminiferal faunas.

Detailed information regarding lower Senonian foraminiferal faunas is available over most of northern Europe, where outcrops provide suitable sections or from the study of borehole material.

During the comparison of described assemblages, as in the study of the English fauna, it became apparent that the more valuable stratigraphic information was provided by the benthonic foraminifera, rather than the planktonic species. The presence of distinct northern European lower Senonian benthonic assemblages, with a geographic distribution from Eire (Barr 1966) to southern Russia (Vasilenko 1961) is suggested. In addition, the stratigraphic relationships of individual taxa are remarkably consistant over the same area, a distance of 4,500 kilometres.

Selected areas are discussed in the light of their palaeogeographic significance and the relationship between their microfaunas is outlined. More particularly, the relationship of these areas to the results of the present research are considered.

The framework upon which this study hangs is the existance of distinct faunal assemblages, which are denoted as Assemblage Zones A to F (Fig. 5:1). The species used to define these zones are recorded from the rest of Europe, although specific names may vary, and it is this fact which allows a broad lower Senonian biostratigraphy to be suggested.

The oldest division of the study, Assemblage Zone A, represents the transition from a Turonian benthonic fauna to that of the Coniacian. For example, Gavelinella sp. B, is simply the final member of the G. tourainensis lineage recorded from the Turonian (Butt 1966).

The fauna of Assemblage Zone A, correlates well with that illustrated from Sainghin-en-Melantois, France by Robazynski (1975). The Turonian - Coniacian boundary at this locality is emphasised by a slight hiatus, marked by a phosphatic hardground.

Above this horizon R. kelleri and V. münsteri were noted for the first time, these two species being characteristic of the zonal assemblage.Two metres higher in the section,Robazynski records Gavelinella aff. vombensis 2, which is known to be identical to Lingulogavelinella sp.A (see Chapter 4), which occurs towards the top of the zone in this country.

There are no other European descriptions of R. kelleri and V. münsteri apart from that of Vasilenko (1961), in which he records the latter as a characteristic species of the Coniacian. However, he does not find R. kelleri until the mid-Santonian. This is not inconsistant with it's present recorded distribution, when it is considered that R. kelleri has two levels of abundance in the English Chalk, the early Coniacian and the early to mid-Santonian. The former is apparently absent in southern Russia.

The lower boundary of Assemblage Zone B is believed to equate with the German concept of the Turonian - Coniacian boundary, as in both countries the horizon is marked by the lowest occurrence of Stensioina granulata (Hiltermann and Koch 1956, 1960). In other areas of Europe this species is recorded within the late Turonian (Brotzen 1945, Gawor-Biedowa and Witwicka 1960), although these authors suggest a predominantly Coniacian distribution. In the Coniacian of the Mangyshlak Peninsula, Vasilenko (op. cit) illustrates an extremely closely related species Stensioina emscherica var. emscherica and in his synonomy he includes Brotzen's (1945) Stensioina prae-exsculpta from the Hollviken boreholes of Sweden.

From the same sections, Vasilenko also records Osangularia whitei var. whitei, and this correlates with the association of this subspecies and S. granulata in this country O. whitei var. whitei is a common member of the assemblages recorded by Brotzen (1936, 1945) and Norling (in Bergström et al 1973) although it's precise range in Southern Sweden has never been given. Brotzen (1945) suggests that is restricted to the Emscherian and Santonian.

Gavelinella thalmanni is also used to define the base of Assemblage Zone B in southern England, and it's recorded geographical distribution includes Eire (Barr 1966), Germany (Koch 1973), southern Sweden (Brotzen 1936, Norling,in Bergström et al 1973), Poland (Gawor-Biedowa and Witwicka 1960) and the Mangyshlak Peninsula (Vasilenko 1961). It is generally considered to range from the base of the Coniacian through the Campanian, although Vasilenko (1961) and Koch (1973) do not record it until the Santonian.

In this country, the lowest occurrence of Stensioina exsculpta exsculpta is consistantly a few metres higher than that of S. granulata, G. thalmanni and O. whitei var. whitei. This stratigraphic relationship has been recorded by Vasilenko (1961) and Koch (in Ernst et al, 1966) indicating a high degree of consistency over a wide area.

A useful datum for regional correlation is the first appearance of Loxostomum eleyi, used to define the base of Assemblage Zone C in the present study. It's range from the mid-Coniacian through the Campanian has previously been noted in the British Isles by Williams-Mitchell (1948) and Barr (1966), however records of its occurrence elsewhere in Europe do not appear to be stratigraphically significant.

The early Santonian assemblage found in southern England is marked by the association of Cibicides beaumontianus, Eponides cf. concinna and Stensioina granulata var. A. This last taxon is very similar to S. granulata var. polonica, an undescribed variety used by Koch (pers. comm.) to mark the base of the Santonian in Germany. Eponides cf. concinna, or closely related forms have been recorded from the early Santonian across northern Europe (Barr 1966, Brotzen 1936, Vasilenko 1961) and it is commonly associated with the appearance of C. beaumontianus. The abundance of this latter species, and related taxa (C. beaumontianus var. A and C. ribbingi), in the early Santonian of northern Europe is believed to be of considerable stratigraphic significance. It has been recorded in the present study, in Eire (Barr), Germany (Koch, 1973) and also in south eastern France (Porthault, 1974).

Slightly higher in the succession the assemblage is joined by Reussella szajnochae praecursor which has a wide distribution in the northern province, and also appears to be present in the Upper Cretaceous of Antigua, B. W. I. (Cushman 1931).

There are distinct early Coniacian and early Santonian foraminiferal assemblages which can both be correlated across northern Europe, on a broad basis, as precise stratigraphical ranges are not always available. The stratigraphic use of benthonic foraminifera, such as those considered above, over a large area demands rapid distribution, despite their benthonic mode of life.

Only C. beaumontianus and C. ribbingi lived attached to plant material, which may have aided their spread during the early Santonian, all the other species were dependant on natural dispersion across the sea floor.

It is acknowledged that the general environment and substrate was relatively consistant across the whole area and there were no physical barriers to prevent rapid migration. Even so, the stratigraphical succession obtained from the benthonic foraminiferal population is proof of their value on an inter-regional basis.

Positive links, based on the benthonic fauna also exist with the Tethyan province. Porthault (1974) in his description of the Upper Cretaceous stratigraphy of the "Fosse Vocontienne" region of south east France, records twenty one benthonic foraminiferal species from the Coniacian and Santonian. Of these, fourteen have been recorded from southern England during the present study.

He describes S. granulata, S. exsculpta and S. gracilis, although from the distribution of the last two, and his photographs of specimens from Puget - Therniers (1970) it is believed that he has confused the two species, as did Hofker (1956). L. eleyi and V. scalariformis are both present in the early Santonian and as noted above, C. beaumontianus is a member of the same assemblage.

More important perhaps, is the link provided by Porthault between the rich Tethyan planktonic foraminiferal assemblage and the less diverse fauna of the northern province. It is believed that the area he discusses lay on one of the routes along which warm water currents, originating in the Tethyan province, were channelled.

The positive areas of the Vosges and the Black Forest were present to the north east, and the Massif Central provided a barrier to the west. The two areas therefore created a corridor into the Wessex -Paris Basin.

A few species of planktonic foraminifera, originally described from the Mediterranean area, occur sporadically through the southern England succession. G. angusticarinata and G. renzi were both described from the Swiss Alps (Gandolfi 1942), G. concavata was described from Palestine (Brotzen 1934) and G. primitiva originates in Tunisia (Dalbiez 1955). G. concavata and G. renzi are the more important of the four as they have virtually a global distribution and are used by van Hinte (1976) as index species for the Santonian and Coniacian respectively.

Moorkens (1969) records both of these species in the Senonian succession of Belgium, but neither have been described from either Holland and Germany (Hofker 1956, Koch 1966 in Ernst et al) or southern Scandinavia (Douglas and Rankin 1969). This would suggest a limited distribution in the Boreal province.

There are numerous discussions of the above four species in the Tethyan area, including Dalbiez (1955), Lehmann (1962), Caron (1966) and Scheibnerova (1968), and the European distribution of G. concavata, G. angusticarinata and G. renzi is given in Figs 7:2-3.The pattern which emerges is one controlled by the lines of ocean current activity, the occurrences of these particular species being situated in areas to which warmer water was able to penetrate from the south.

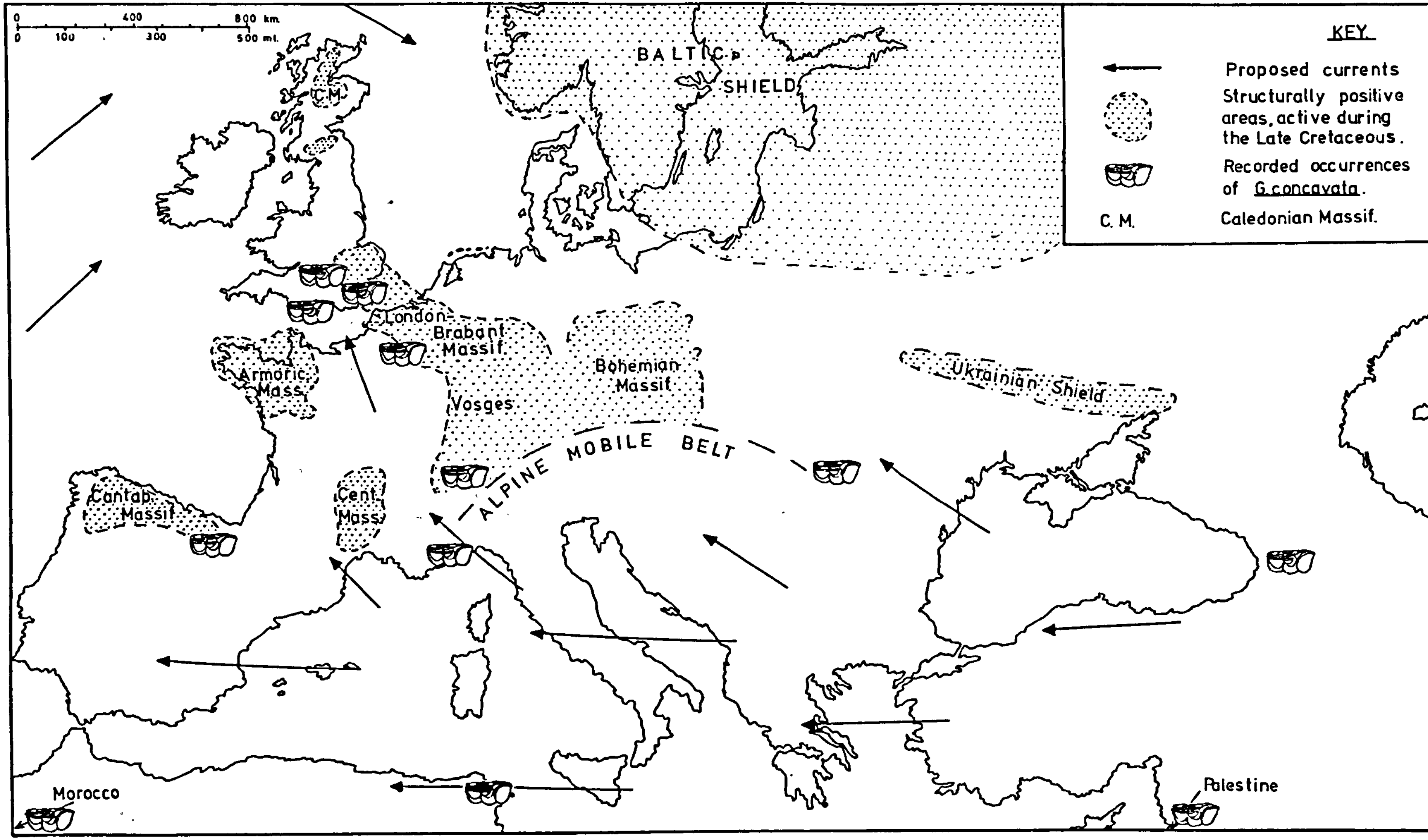


Fig. 7:2

The European distribution of Globotruncana concavata (Brotzen)

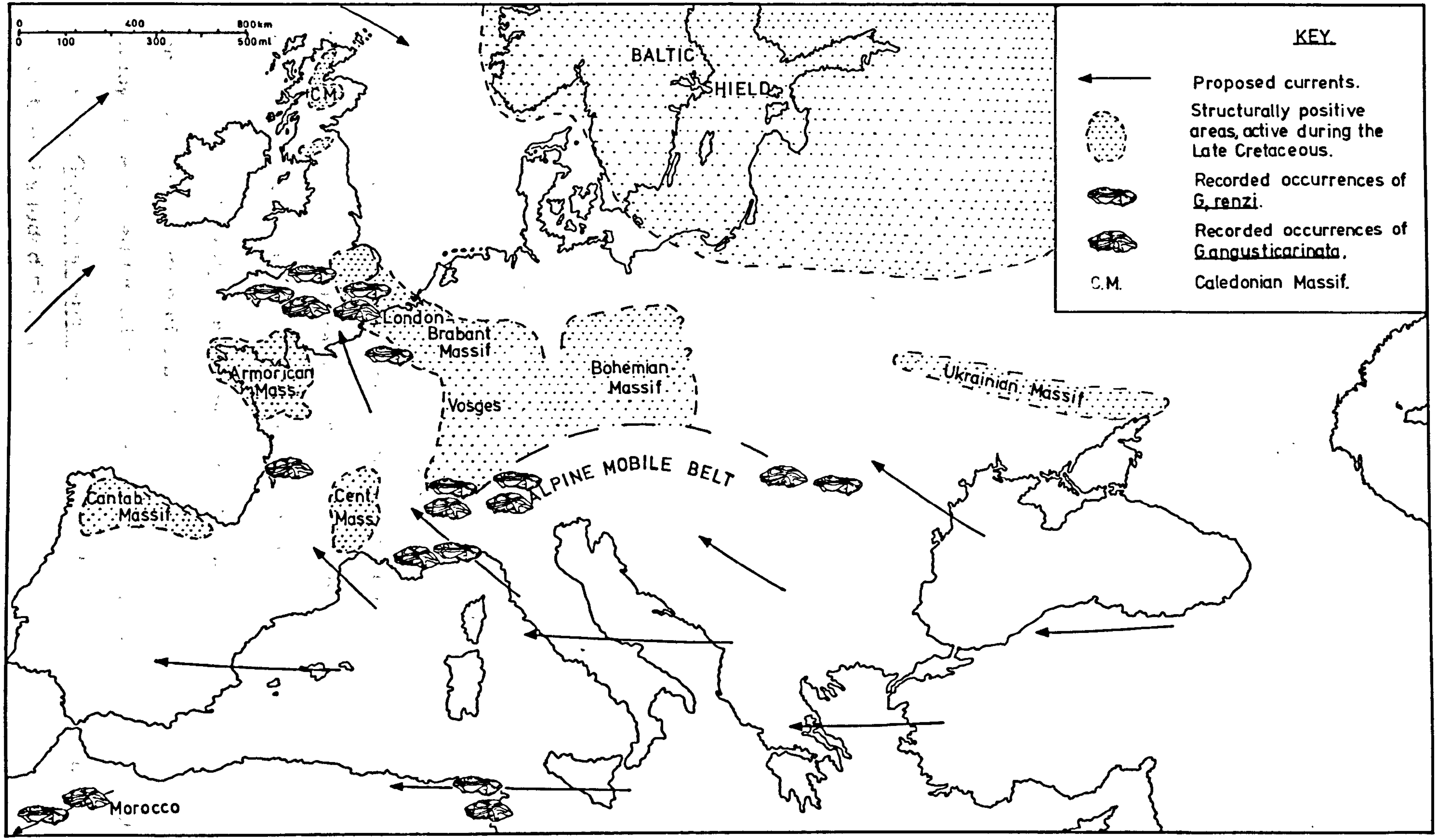


Fig. 7:3 The European distribution of Globotruncana renzi (Gandolfi) & G. angusticarinata (Gandolfi)

The sporadic distribution of Tethyan species in the English Chalk is believed to be a result of it's palaeolatitude during the lower Senonian. Southern England and Germany lay on a similar Late Cretaceous palaeolatitude at about 38°N, however the former's position, directly to the north of the Wessex - Paris Basin, allowed the stronger pulses of warmer water to reach the area.

G. angusticarinata, G. concavata and G. renzi have all been described from Central Europe and the Carpathian region (Tollman 1960, Scheibnerova 1968 and Hanslikova 1972), areas which lay to the east of the Bohemian Massif. This suggests that warm currents were passing across eastern Europe during the lower Senonian, along the trend of the Danish - Polish Trough. However the absence of recorded occurrences a little further to the north, in Germany indicates that they were not able to penetrate as far into the Boreal province along this route.

Southern England and Belgium emerge as a transitional buffer zone between the Tethyan and Boreal provinces, a role already suggested for the English Chalk by Douglas and Rankin (1969, table 2). The planktonic species diversity of the present study lies between the rich Tethyan fauna described by numerous authors including Porthault (1974) and the typically impoverished Boreal assemblage described by Douglas and Rankin (op. cit.)

This is briefly summarised in Table 2, in which the geographical distribution of planktonic species encountered in this study is recorded for other ones of Europe, arranged from north to south. Globotruncana sigali Reichel and G. tarfayensis (Lehmann) have been included simply to give a balance between the northern

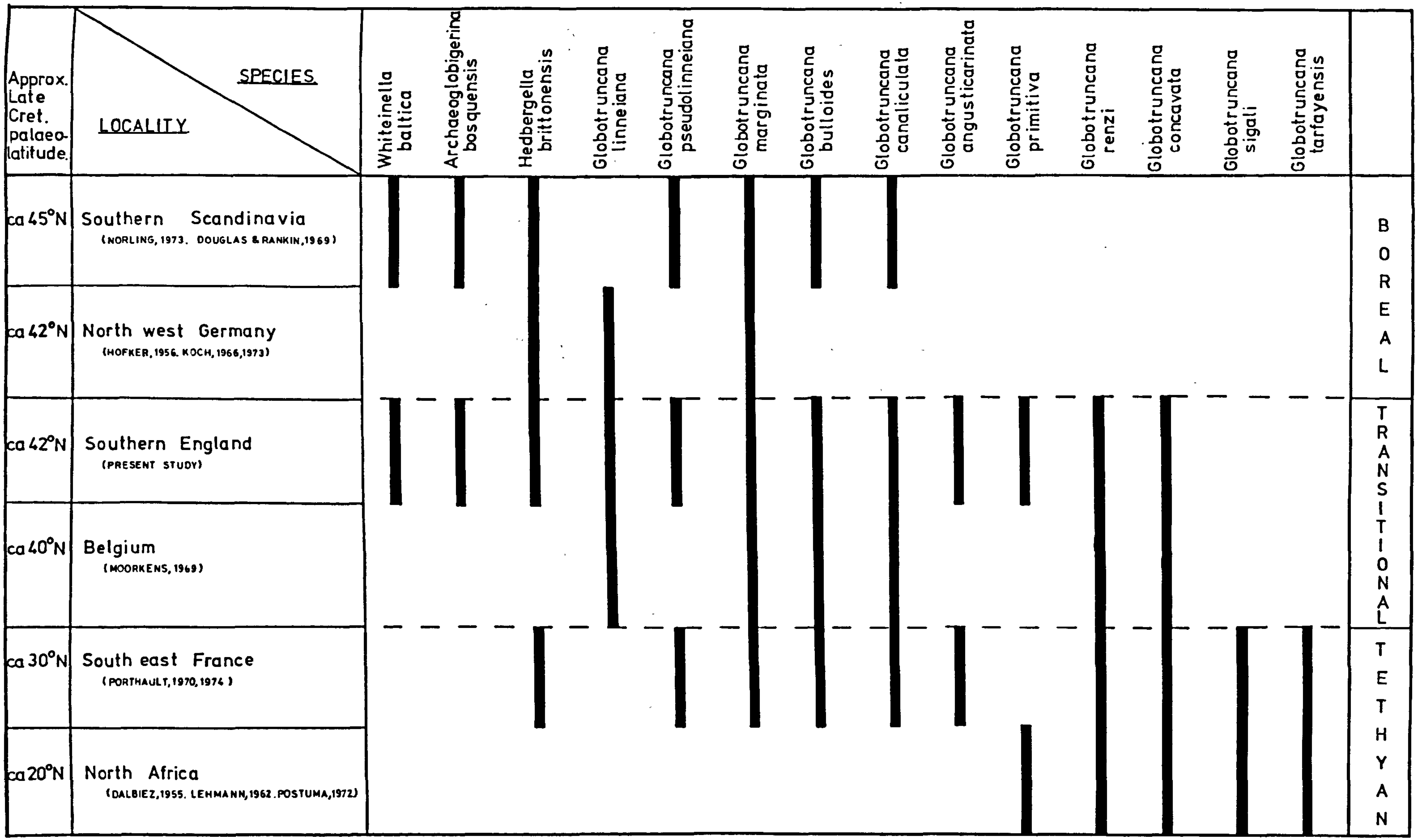


Table 2 Geographical distribution of selected planktonic species

and southern provinces.

The work of Bé and Tolderlund (1971) on the present distribution of planktonic foraminifera in the oceanic areas, suggests that nine planktonic assemblages can be identified in the surface waters, following more or less latitudinal belts. However, they maintain that only five broader divisions can be recorded using sea floor samples of dead material. In present - day oceans the equatorial to polar temperature gradient is much greater than it would have been in the Upper Cretaceous Epoch, if a non-glacial interpretation is correct, and there is little evidence for any polar ice during the time in question.

By inference, it would seem that during the Upper Cretaceous it is only possible to recognise three such planktonic assemblages. The Boreal fauna, the more equatorial Tethyan fauna, and the Austral fauna in the southern hemisphere which has been described and compared with European faunas by Scheibnerova (1972) and Edgell (1957).

APPENDIX A.

NOTES ON THE AFFECT OF LITHOLOGICAL VARIATIONS ON MICROFAUNAL SAMPLES.

Throughout this study a standard sampling interval has been maintained for any one section, with the intention that no litho-logical bias would be imposed on the results obtained. However, the samples collected were by no means lithologically uniform.

The Chalk of southern England has undergone a complex diagenetic history, and the resultant lithological variation affects the physical properties of the rock through it's geographical and stratigraphical distributions. These properties affect the processing methods used to extract a microfauna, and any micropalaeontological study must acknowledge that these two factors may modify the faunal assemblage obtained.

Indurated chalk.

For the most part, samples used have been soft chalks, capable of being broken down by slight crushing in a mortar and pestle, followed by washing through a sieve, as described in Chapter 2. Some of the samples from the lower part of the succession on the Isle of Wight required greater use of the mortar and pestle. Despite the induration of the rock, caused by tectonic deformation, an acceptable fauna was obtained from the majority of the samples. Similar alteration of the chalk of Arish Mell, Dorset meant that examination of the samples could only be done by using thin sections.

Phosphatisation.

The phosphatisation of chalks, and the production of nodular fabrics and hardgrounds has a similar affect to that described above. Several samples from the Annis' Knob section, of south east Devon, had to be thin sectioned in order to examine the fauna, and obviously no faunal counts were taken for these assemblages.

Marl seams.

Decalcification of a sample, with the resultant loss of calcareous taxa has only been noted at one horizon. This was in a sample of the well developed marl seam used to mark the junction of the *Micraster* Zones at Freshwater Bay (Sample FW 19). The microfauna obtained comprised 90% agglutinating species, with siliceous sponge spicules and phosphatic teeth and microcoprolites.

Flint "meal" samples.

Several samples were collected in the form of flint "meal", from the interiors of cavernous nodular flints, or from between compressed tabular flints.

The microfaunas obtained were almost totally silicified, and they normally included common sponge spicules in addition to foraminifera and ostracods.

The unusual feature of these faunas was the relatively high planktonic/benthonic ratio, when compared with that of the surrounding chalk. The planktonic foraminifera made up approximately 40-50 % of the total faunal assemblage, and this compares with a figure rarely above 10% for the rest of the succession.

It should be noted that only a few flint meal faunas were examined, from Arish Mell, Kent and the Isle of Wight, and the above figures are only approximate.

A typical example taken from the well documented Langdon Stairs section of south east Kent was examined as follows. The sample was scraped from between the two thin ($<$ 1cm) tabular flints which together constitute the "M. coranguinum tabular" of Rowe(1900). A sample was also taken for comparison from the chalk immediately below the flint band. The vertical distance between the two samples was less than 2 cms.

The general analysis of the faunas is as follows:-

	Chalk sample (LS32)	Flint "Meal" sample (LS33)
Agglutinating foraminifera	39.58%	10.21%
Calcareous benthonic foraminifera	57.05%	29.32%
Planktonic foraminifera	3.30%	60.44%

There is a striking contrast between the two, which demands comment even if a satisfactory explanation is not wholly possible. It is worth noting that the flint sample also yielded a specimen of Globotruncana concavata (Brotzen), which as already described, is rare in this country.

The preferential preservation of the planktonic assemblage is unlikely to have occurred because of an original concentration of planktonic foraminifera at this particular level. Secondary concentration during diagenesis, and the production of the flint, is also unacceptable, as it is difficult to envisage a process by which this could happen.

The simplest explanation is that the planktonic foraminifera are silicified, and therefore more resistant to breakage, in addition to being protected within the flint. When they are washed out of the sample little or no loss occurs due to breakage. By comparison, the calcareous, planktonic foraminifera of the "normal" chalk are often fractured, this being visible in thin section. When the sample is processed and disaggregated the fractured foraminifera will also break up, leaving a high benthonic count, as these taxa are normally more durable.

This suggests that the true planktonic/benthonic ratio for the Chalk is only seen in faunas protected within flints, and Barr (1962) also noted how well preserved these faunas were. However these high counts do not fit with the general trends seen in the lower Senonian chalk of southern England. Higher planktonic counts are obtained from the indurated chalk of the M. cortestudinarium Zone than from the softer chalks of the overlying zones. This is in contrast to what would be expected from the amount of processing required by the former.

This general trend is encountered in all the sections studied, and is therefore consistant across the country. The isolated occurrence of high counts from within flints provide the exception to a general rule, particularly when they are located, like the Kent sample listed above, in part of the succession with a normally low count.

This data regarding flint "meal" faunas casts some doubt on the calculation and interpretation of the planktonic/benthonic ratio for chalk samples. The planktonic fauna of the lower Senonian in southern England is of little use for detailed regional correlation, and the the benthonic microfauna provides a very acceptable alternative. For this reason little emphasis has been placed on the planktonic element of fauna in this study.

Detailed work comparing flint "meal" faunas and those of the adjacent chalk, carried out in a stratigraphic context, may provide an explanation to the problem outlined above. Unfortunately this was not possible within the scope of the present study.

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PLATES

PLATE 1

Ammodiscacea, Lituolacea

1. Ammodiscus cretaceus (Reuss). Assemblage zone E. South east Kent. x 35.

2. Reophax sp. A. Assemblage zone C. Freshwater Bay Isle of Wight. x 75.

3. Ammobaculites cf. rowei. Barnard and Banner. Assemblage zone A. S.E. Kent. x 45.

4. Spiroplectammina anceps (Reuss). Assemblage zone C. Newton-by-Castleacre, Norfolk. x 75.

5. Spiroplectammina anceps (Reuss). Assemblage zone C. Freshwater Bay, Isle of Wight. x 60.

6. Bigenerina sp. A. Assemblage zone D. Quidhampton Wiltshire. x 75.

7. Verneuilina münsteri (Reuss). Assemblage zone C. South east Kent. x 35.

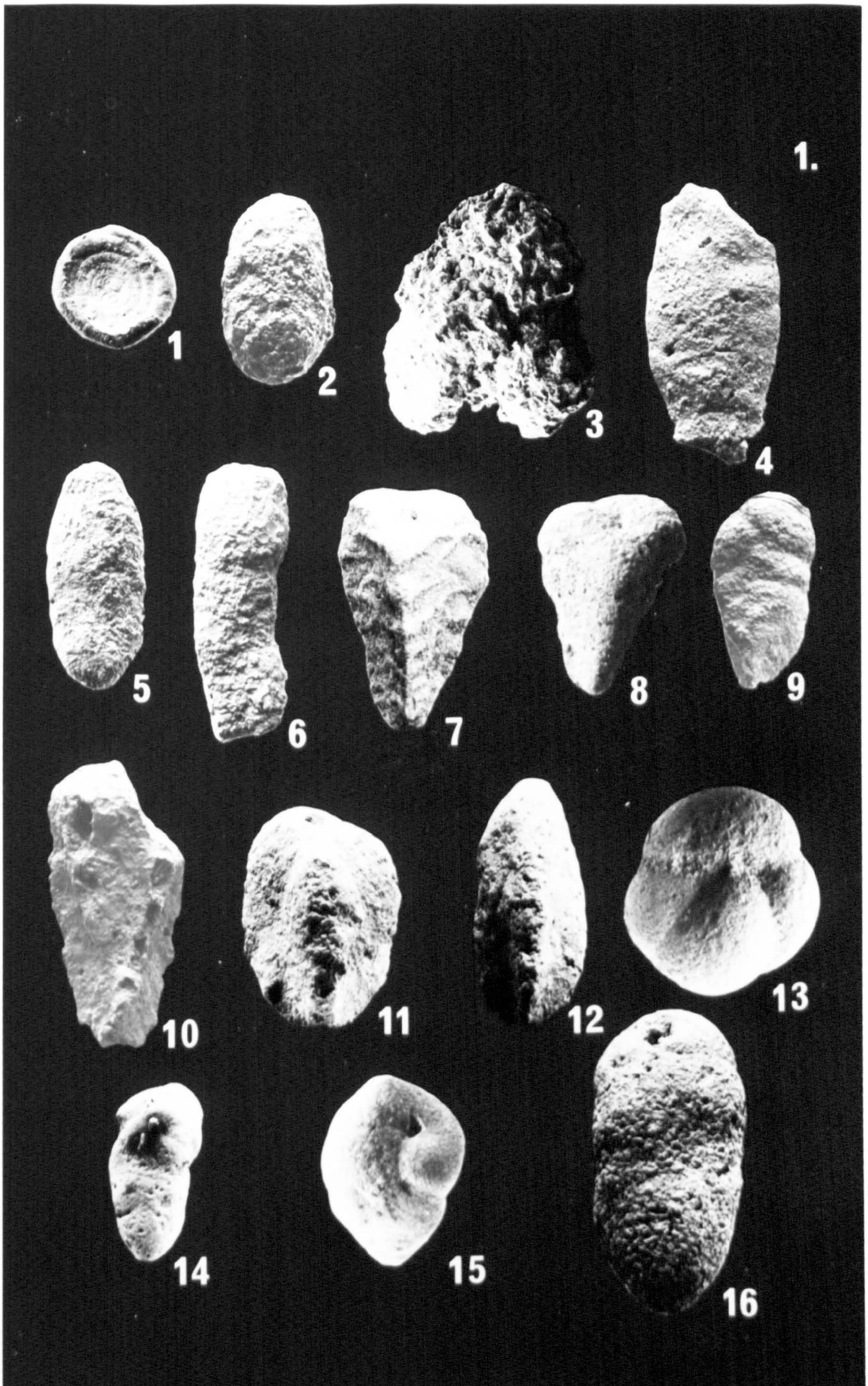
8. Verneuilina sp. A. Assemblage zone A. B.H. No. 25 Thames Barrier Site Investigation. x 60.

9. Gaudryina frankei Brotzen. Assemblage zone C. Quidhampton Wiltshire. x 60.

10. Gaudryina jonesiana Wright. Assemblage zone F. Kelveden, Essex. x 80.

11. Tritaxia tricarinata (Reuss). - typical form. Assemblage zone A. B.H. No. 25 Thames Barrier Site Investigation. x 70.

12. Tritaxia tricarinata (Reuss). - elongate form. Assemblage zone D. B.H. Bo. 25 Thames Barrier Site Investigation. x 45.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13. Arenobulimina courta (Marie). Assemblage zone B. Freshwater Bay, Isle of Wight. x 80.

14. Arenobulimina cf. polonica Gawor - Biedowa. Assemblage zone B. B.H. 25 Thames Barrier Site Investigation. x 40.

15. Arenobulimina obliqua (d'Orbigny) Assemblage zone B. South east Kent. x 45.

16. Arenobulimina sp. A. Assemblage zone C. Freshwater Bay, Isle of Wight. x 80.

PLATE 2

Lituolacea, Nodosariacea.

1. Dorothia pupa (Reuss). Assemblage zone C. Quidhampton, Wiltshire. x 80.

2. Marssonella oxycona. (Reuss). Assemblage zone A. B.H. No. 25 Thames Barrier Site Investigation. x 75.

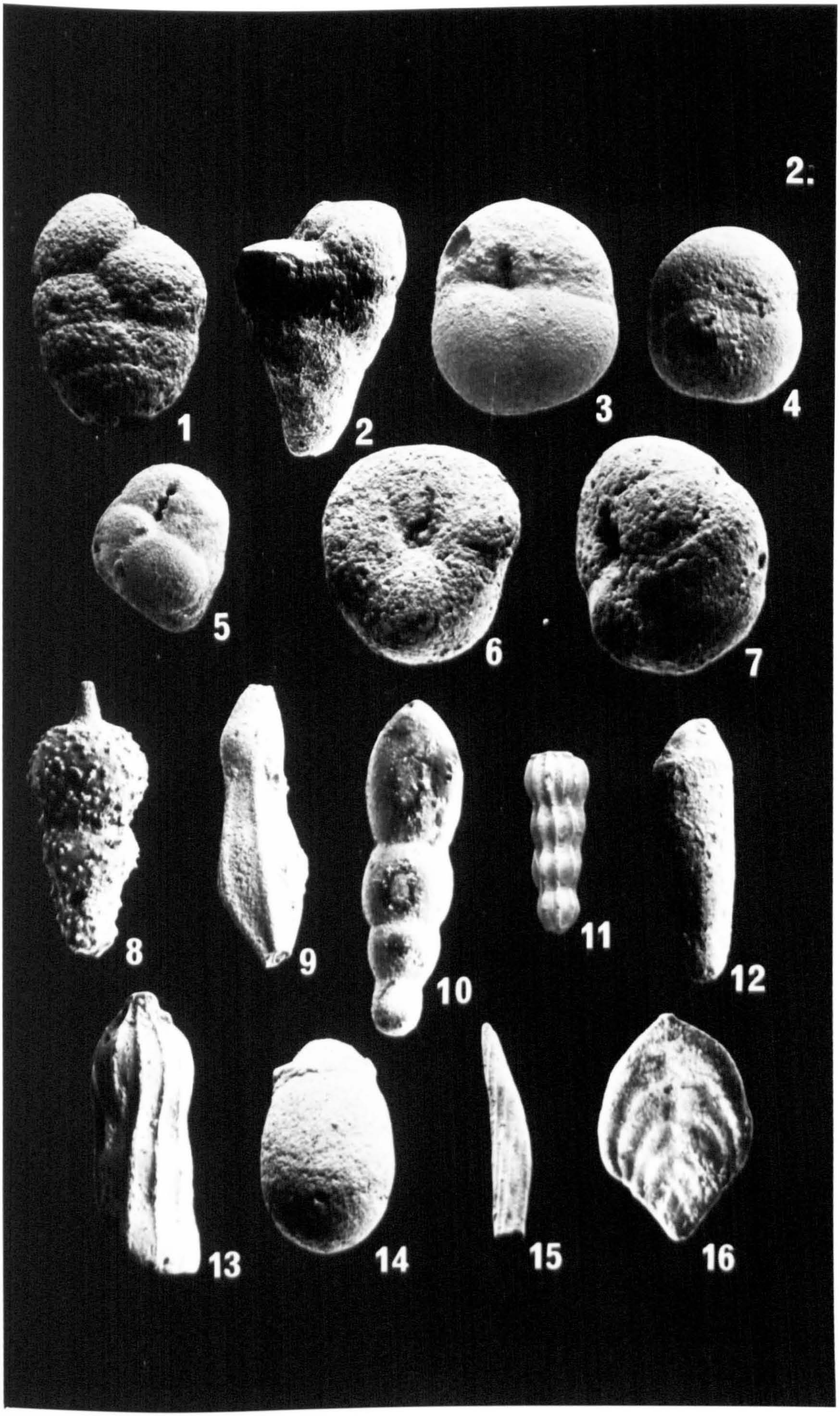
3. Eggerellina gibbosa var. globulosa Marie. Apertural face Assemblage zone F. Kelveden, Essex. x 80.

4. Eggerellina gibbosa var. globulosa Marie, Spiral view, Assemblage zone C. Quidhampton, Wiltshire. x 60.

5. Eggerellina gibbosa var. conica Marie, Assemblage zone B. South east Kent. x 80.

6. Ataxophragmium variabile (d'Orbigny). Apertural face Assemblage zone A. B.H. 25 Thames Barrier Site Investigation. x 55.

7. Ataxophragmium variabile (d'Orbigny). Side view. Assemblage zone A. B.H. 25. Thames Barrier Site Investigation. x 50.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8. Nodosaria aspera Reuss. Assemblage zone E. South east Kent. x 75.

9. Nodosaria gracilitatis Cushman. Assemblage zone D. Culver Cliff, Isle of Wight. x 75.

10. Nodosaria naumanni Reuss. Assemblage zone B. South east Kent. x 75.

11. Nodosaria zippei Reuss. Assemblage zone B. South east Kent. x 20.

12. Nodosaria sp. A Assemblage zone A, Beer, South east Devon. x 40.

13. Nodosaria sp. B. Assemblage zone C. South east Kent. x 70.

14. Nodosaria sp. c. Assemblage zone B. B. H. No. 25 Thames Barrier Site Investigation. x 80.

15. Citharina cf. strigillata (Reuss). Assemblage zone B. South east Kent. x 75.

16. Citharinella sp. A. Assemblage zone D. Quidhampton Wiltshire. x 60.

PLATE 3

Nodosariacea.

1. Dentalina catenula Reuss. Assemblage zone C. Newton-by-Castleacre, Norfolk. x 80.

2. Dentalina catenula Reuss. Assemblage zone D. South east Kent. x 70.

3. Dentalina megalopolitana Reuss. Assemblage zone B. B. H. No. 25 Thames Barrier Site Investigation. x 25.

4. Dentalina cf. monile (vonHagenow). Assemblage zone F. Kelveden, Essex. x 195.

5. Dentalina nana Reuss. Assemblage zone C. South east Kent. x 40.

6. Dentalina pseudofiliformis Brotzen. Assemblage zone B. South east Kent. x 35.

7. Dentalina cf. wimani Brotzen. Assemblage zone F. Culver Cliff, Isle of Wight. x 80.

8. Frondicularia angulosa d'Orbigny. Assemblage zone D. Quidhampton, Wiltshire. x 80.

9. Frondicularia archiaciana d'Orbigny. Assemblage zone D. Quidhampton, Wiltshire. x 60.

10. Frondicularia goldfussi Reuss. Assemblage zone C. South east Kent. x 40.

11. Frondicularia inversa Reuss. Assemblage zone D. Quidhampton, Wiltshire. x 30.

12. Frondicularia schenkei Brotzen. Assemblage zone C. South east Kent. x 40.

13. Frondicularia sp. A Assemblage zone A. B.H. No. 25 Thames Barrier Site Investigation. x 30.

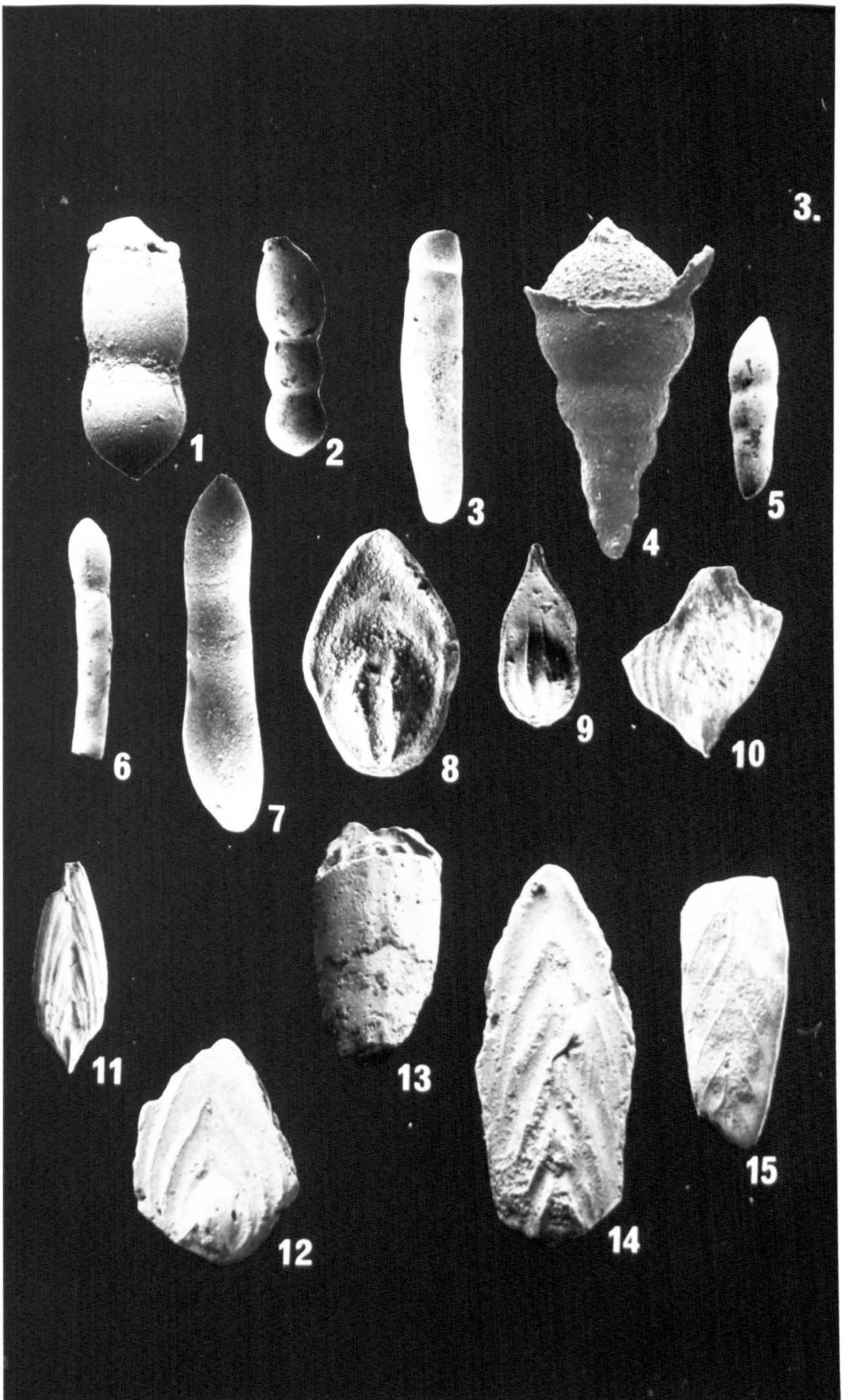
14. Frondicularia sp. C Assemblage zone B. South east Kent. x 60.

15. Frondicularia striatula Reuss. Assemblage zone D. Burnham overy, Norfolk. x 40.

PLATE 4

Nodosariacea

1. Lagena ellipsoidalis Schwager. Assemblage zone C. Freshwater Bay, Isle of Wight. x 75.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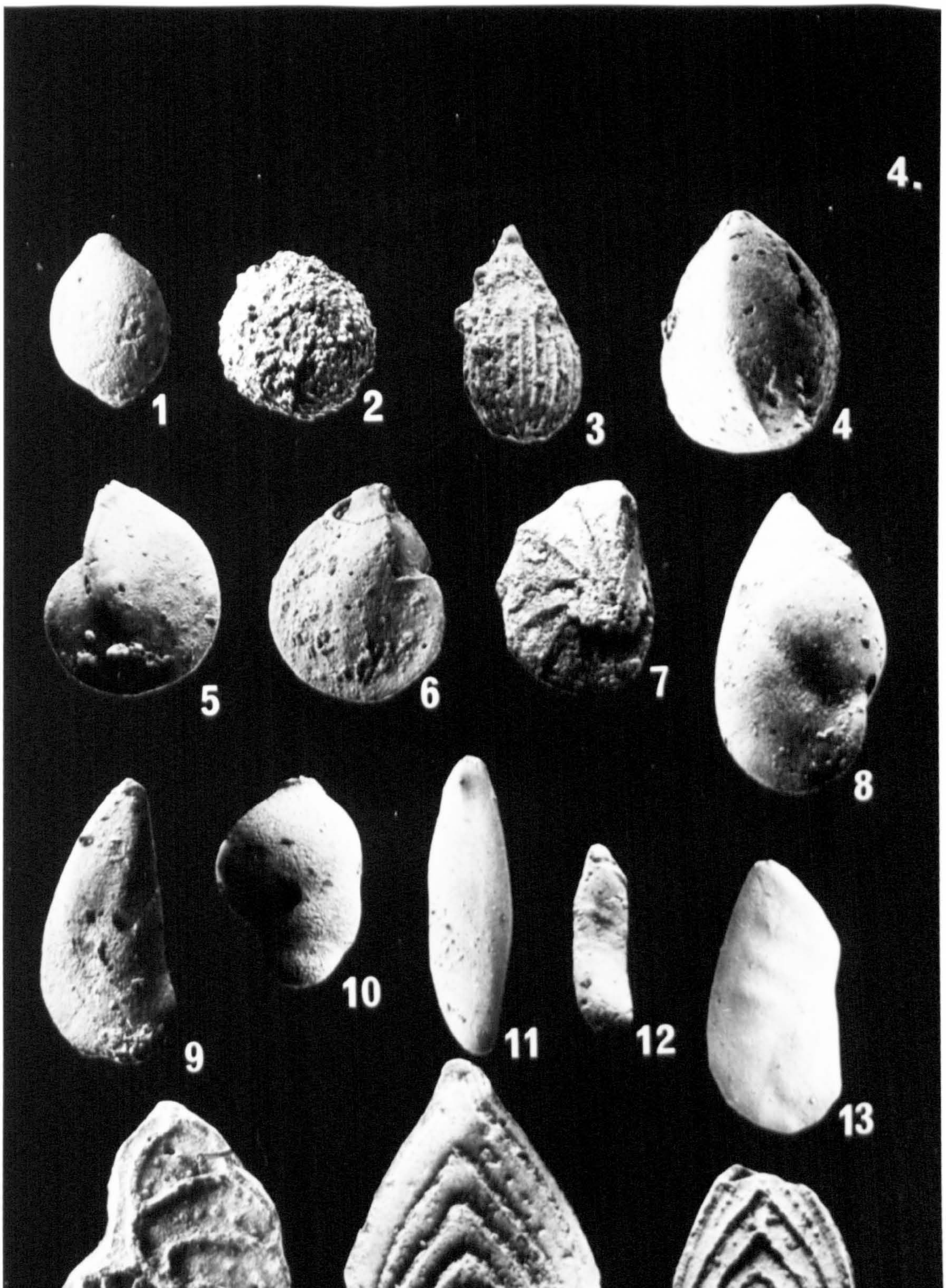
2. _Lagena hispida_ Reuss. Assemblage zone D, Helhoughton, Norfolk. x 75.
3. _Lagena isabella_ d'Orbigny. Assemblage zone A. Beer. South east Devon. x 75.
4. _Lenticulina ovalis_ Reuss. Assemblage zone C. Freshwater Bay, Isle of Wight. x 85.
5. _Lenticulina rotulata_ (Lamark). Assemblage zone F. Culver Cliff, Isle of Wight. x 35.
6. _Lenticulina rotulata_ (Lamark). Assemblage zone D. South east Kent. x 40.
7. _Lenticulina rotulata_ (Lamark). Assemblage zone A. Beer, South east Devon. x 40.
8. _Lenticulina_ sp. A cf _L. pseudonavicula_ (Marie). Assemblage zone D. Helhoughton, Norfolk. x 75.
9. _Lenticulina_ sp. B Assemblage zone C. Newton-by-Castleacre, Norfolk. x 75.
10. _Marginulina bullata_ Reuss. Assemblage zone D. Quidhampton, Wiltshire. x 80.
11. _Marginulina_ cf. _compressa_ (d'Orbigny). Assemblage zone C. Newton-by-Castleacre, Norfolk. x 40.
12. _Marginulina_ sp. A. Assemblage zone F. Culver Cliff, Isle of Wight. x 15.
13. _Marginulina_ sp. B. Assemblage zone D. Quidhamton, Wiltshire. x 30.
14. _Neoflabellina baudouiniana_ (d'Orbigny). Assemblage zone C. South east Kent. x 80.
15. _Neoflabellina deltoidea_ (Wedekind). Assemblage zone C. South east Kent. x 80.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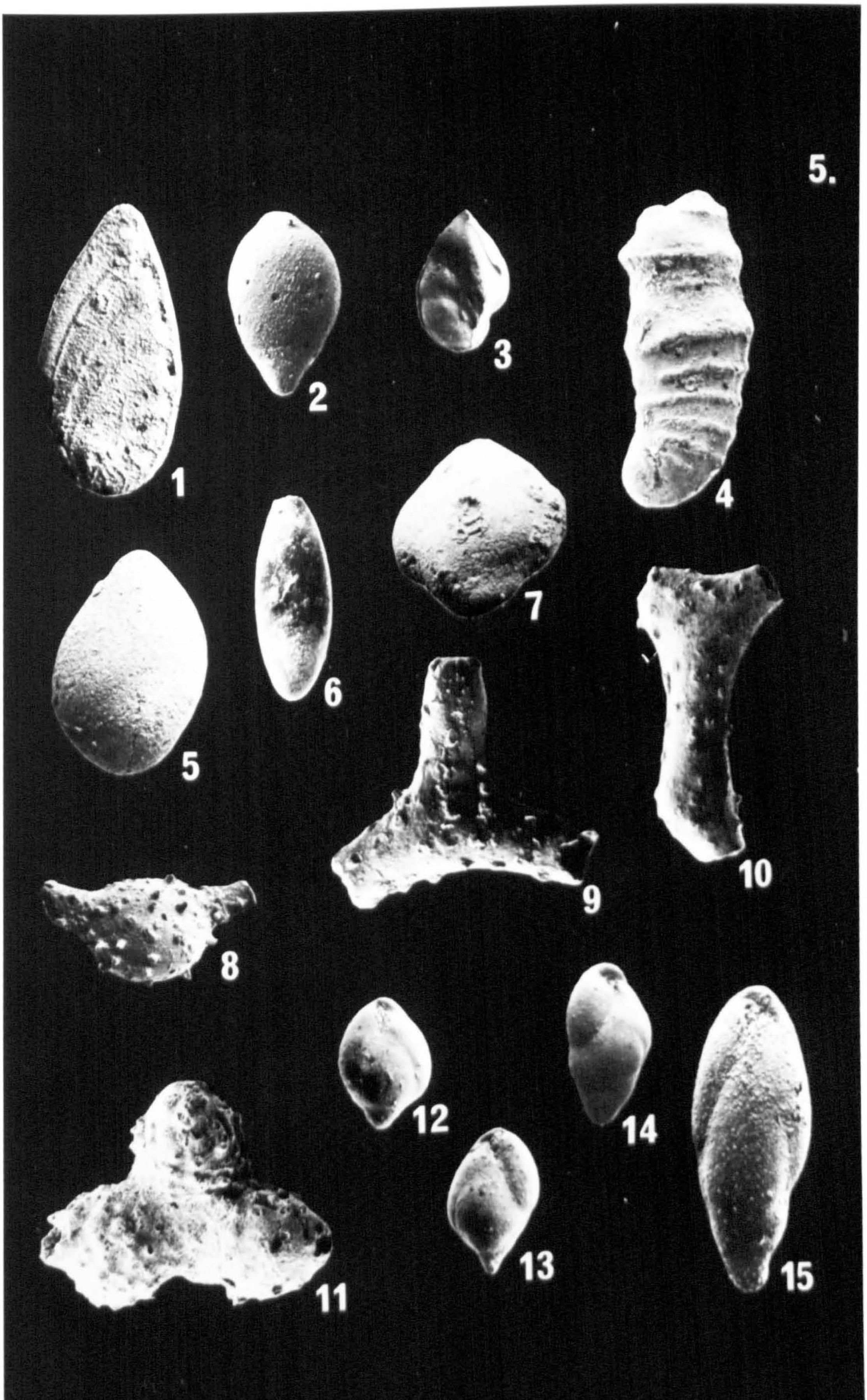
16. Neoflabellina praerugosa Hiltermann. Assemblage zone C. South east Kent. x 65.

PLATE 5

Nodosariacea, Buliminacea

1. Planularia liebusi Brotzen. Assemblage zone B. South east Kent. x 75.
2. Pseudonodosaria obesa (Loeblich and Tappan). Assemblage zone E. Quidhampton, Wiltshire. x 75.
3. Saracenaria triangularis (d'Orbigny). Assemblage zone C. Newton-by-Castleacre, Norfolk. x 30.
4. Vaginulinopsis scalariformis Porthault. Assemblage zone C. South east Kent. x 40.
5. Globulina lacrima Reuss. Assemblage zone A. Beer, South east Devon. x 80.
6. Globulina prisca Reuss. Assemblage zone E. Freshwater Bay, Isle of Wight. x 60.
7. Guttulina trigonula (Reuss). Assemblage zone A. South east Kent. x 80.
8. Ramulina aculeata (d'Orbigny). Assemblage zone C. Newton-by-Castleacre, Norfolk. x 75.
9. Ramulina aculeata (d'Orbigny). Assemblage zone B. South east Kent. x 80.
10. Ramulina aculeata (d'Orbigny). Assemblage zone C. South east Kent. x 45.
11. Ramulina sp. A. Assemblage zone B. South east Kent. x 120.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12. Praebulimina reussi (Morrow). Assemblage zone D. South east Kent. x 60.

13. Praebulimina reussi (Morrow). Assemblage zone C, Newton-by-Castleacre, Norfolk. x 60.

14. Praebulimina obtusa (Reuss). Assemblage zone D. Quidhampton, Wiltshire. x 75.

15. Praebulimina parva (Franke). Assemblage zone D. Quidhampton, Wiltshire. x 200.

PLATE 6

Buliminacea, Discorbacea, Globigerinacea

1. Pyramidina cf. buliminoides (Brotzen). Assemblage zone F. Kelveden, Essex. x 175.

2. Eouvigerina aculeata (Ehrenberg). Assemblage zone A. South east Kent. x 205.

3. Eouvigerina aculeata (Ehrenberg). Assemblage zone C. Newton-by-Castleacre, Norfolk. x 160.

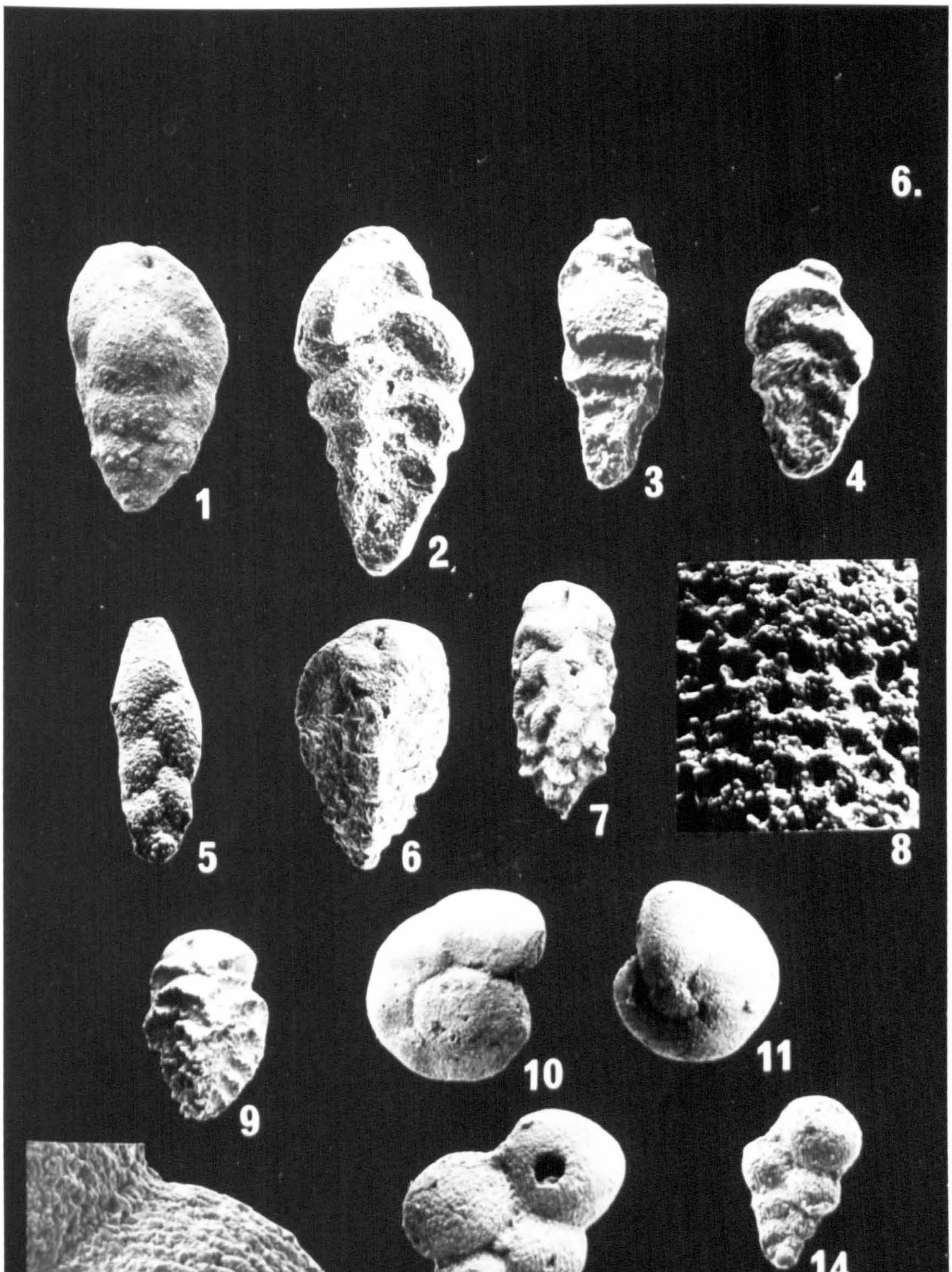
4. Eouvigerina stormi Brotzen. Assemblage zone C. B.H. No. 25. Thames Barrier Site Investigation. x 185.

5. Eouvigerina sp. C. Assemblage zone D. South east Kent. x 160.

6. Reussella kelleri Vasilenko. Assemblage zone B. South east Kent. x 80.

7. Reussella kelleri Vasilenko. Assemblage zone C. Newton-by-Castleacre, Norfolk. x 60.

8. Enlargement of perforate chamber wall, Reussella kelleri (fig. 7). x 1,200.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9. Reussella szajnochae (Grzybowski) praecursor Klasz and Knipscheer. Assemblage zone F. Kelveden, Essex. x 65.

10. Valvulineria lenticula (Reuss). Spiral view. Assemblage zone A. South east Kent. x 80.

11. Valvulineria lenticula (Reuss). Umbilical view. Assemblage zone B. South east Kent. x 80.

12. Heterohelix globulosa (Ehrenberg). Assemblage zone C. Newton-by-Castleacre, Norfolk. x 265.

13. Striate ornament on chamber wall of Heterohelix globulosa (fig. 12). x 1,000.

14. Heterohelix reussi (Cushman). Assemblage zone D. Quidhampton, Wiltshire. x 120.

15. Heterohelix reussi (Cushman). Assemblage zone C. Freshwater Bay, Isle of Wight. x 120.

PLATE 7

Globigerinacea

1. Globigerinelloides asperus (Ehrenberg). Assemblage zone D. Helhoughton, Norfolk. x 150.

2. Globigerinelloides ehrenbergi (Barr). Assemblage zone E. South east Kent. x 180.

3. Globigerinelloides rowei (Barr). Assemblage zone F. Witham, Essex. x 150.

4. Hedbergella brittonensis Loeblich and Tappan. Spiral view. Assemblage zone B. South east Kent. x 80.

5. Hedbergella brittonensis Loeblich and Tappan. Side view. Assemblage zone B. South east Kent. x 80.

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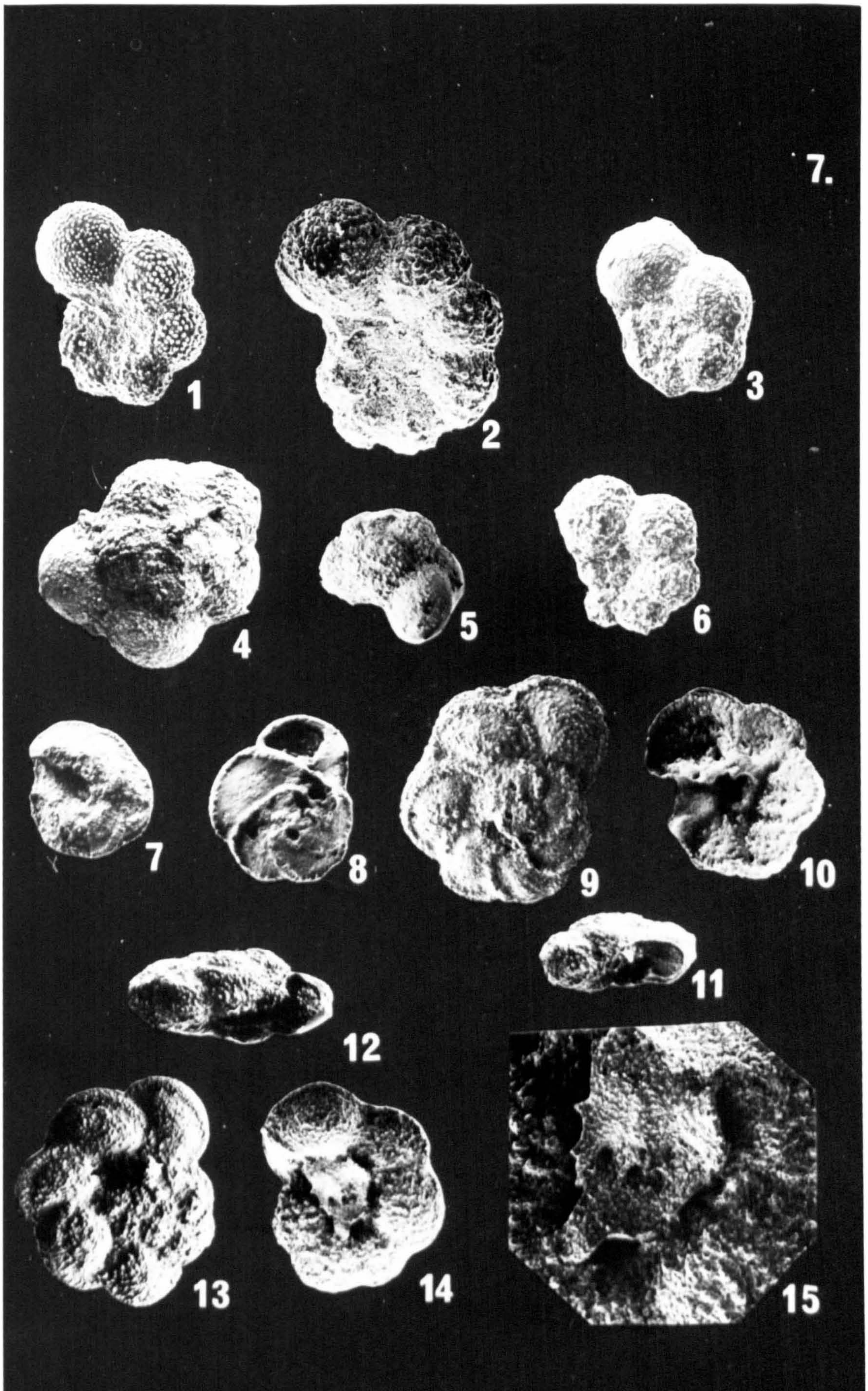


6. Hedbergella planispira (Tappan). Assemblage zone A. South east Kent. x 115.
7. Globotruncana cf angustricaninata (Gandolfi). Umbilical view. Assemblage zone B. B.H. No.25. Thames Barrier Site Investigation. x 50.
8. Globotruncana cf angusticarinata (Gandolfi). Spiral view. Assemblage zone B. B.H. No.25. Thames Barrier Site Investigation. x 60.
9. Globotruncana bulloides Vogler. Spiral view. Assemblage zone B. South east Kent. x 80.
10. Globotruncana bulloides Vogler. Umbilical view. Assemblage zone B. South east Kent. x 80.
11. Globotruncana bulloides Vogler. Side view. Assemblage zone C. Newton-by-Castleacre, Norfolk. x 60.
12. Globotruncana canaliculata (Reuss). Side view. Assemblage zone D. Helhoughton, Norfolk. x 55.
13. Globotruncana canaliculata (Reuss). Spiral view. Assemblage zone C. Freshwater Bay, Isle of Wight. x 75.
14. Globotruncana canaliculata (Reuss). Umbilical view. Assemblage zone F. Witham, Essex. x 65.
15. Enlargement of umbilical area with tegilla, G. canaliculata (fig. 14).

PLATE 8

Globigerinacea

1. Globotruncana concavata Brotzen. Spiral side. Assemblage zone F. Kelveden, Essex. x 75.
2. Globotruncana concavata Brotzen. Umbilical side. Assemblage zone F. Kelveden, Essex. x 75.

3. Globotruncana concavata Brotzen. Side view. Assemblage zone D. Quidhampton, Wiltshire. x 85.

4. Globotruncana linneiana (d'Orbigny). Side view. Assemblage zone F. Kelveden, Essex. x 65.

5. Globotruncana linneiana (d'Orbigny). Spiral view. Assemblage zone D. Newton-by-Castleacre, Norfolk. x 60.

6. Globotruncana linneiana (d'Orbigny). Umbilical view. Assemblage zone F. Kelveden, Essex. x 60.

7. Globotruncana marginata (Reuss). Umbilical view. Assemblage zone. D. Newton-by-Castleacre, Norfolk. x 60.

8. Globotruncana marginata (Reuss). Spiral view. Assemblage zone E. B.H. No. 19. Thames Barrier Site Investigation. x 60.

9. Globotruncana marginata (Reuss). Side view. Assemblage zone D. South east Kent. x 60.

10. Globotruncana primitiva Dalbiez. Umbilical view. Assemblage zone B. B.H. No. 25. Thames Barrier Site Investigation. x 60.

11. Globotruncana primitiva Dalbiez. Spiral view. Assemblage zone B. B.H. Bo. 25. Thames Barrier Site Investigation. x 55.

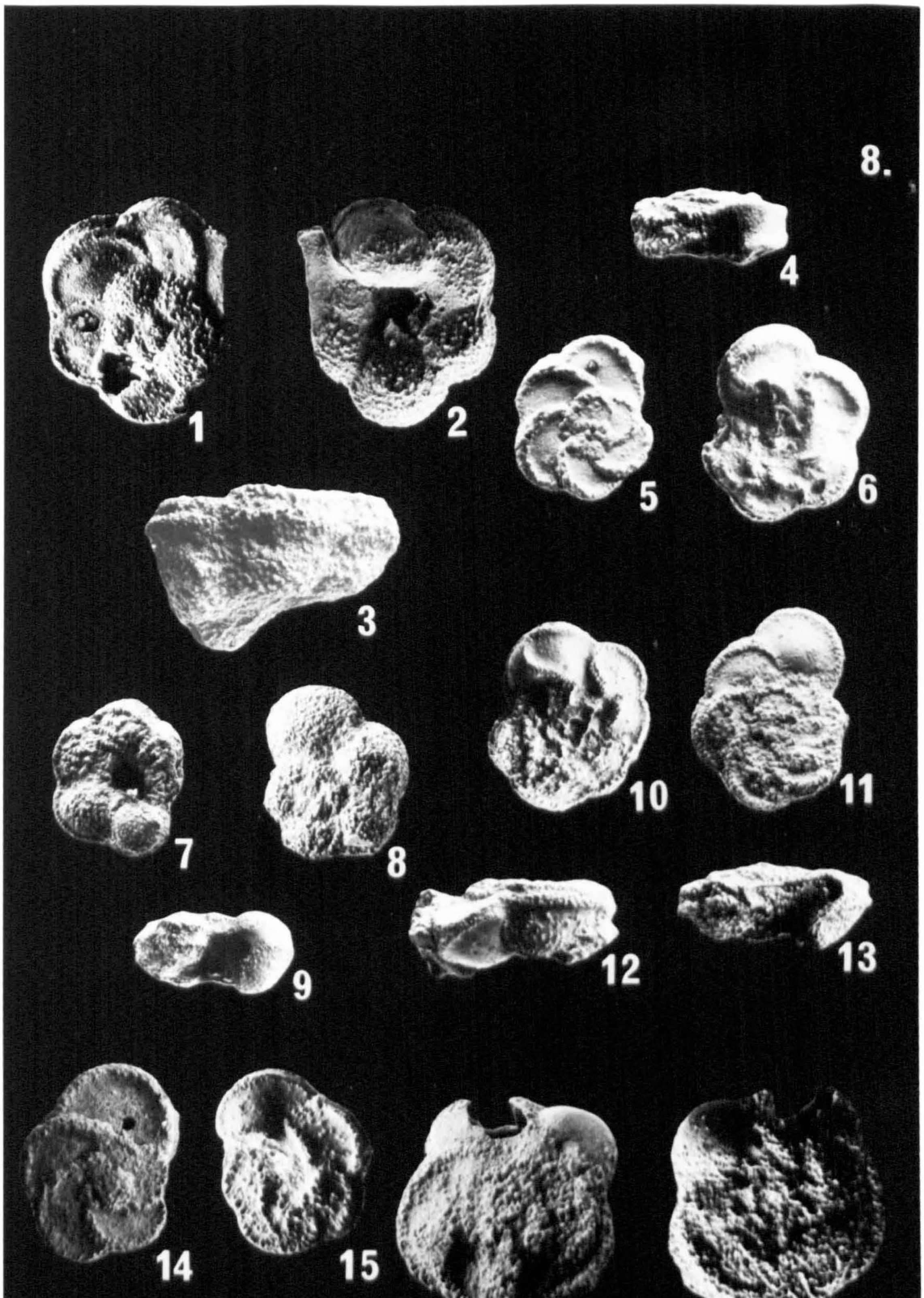
12. Globotruncana primitiva Dalbiez. Side view. Assemblage zone B. B.H. Bo. 25. Thames Barrier Site Investigation. x 60.

13. Globotruncana primitiva Dalbiez. Side view with aperture. Assemblage zone D. Quidhampton, Wiltshire. x 65.

14. Globotruncana pseudolinneiana (Pessagno). Spiral view. Assemblage zone B. South east Kent. x 60.

15. Globotruncana pseudolinneiana (Pessagno). Umbilical view. Assemblage zone A. B.H. No. 25. Thames Site Investigation. x 55.

16. Globotruncana pseudolinneiana (Pessagno). Side view. Assemblage zone A. B.H. No. 25. Thames Barrier Site Investigation. x 60.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17. Globotruncana renzi (Gandolfi). Spiral view.
Assemblage zone. D. Quidhampton, Wiltshire. × 70.

18. Globotruncana renzi (Gandolfi). Umbilical view.
Assemblage zone D. Quidhampton, Wiltshire. × 70.

PLATE 9.

Thin Sections. (Globigerinacea).

1. Globotruncana c. f. angusticarinata (Gandolfi). Assemblage zone A. Beer South east Devon. (x 130). Specimen within a biomicritic chalk, rich in calcispheres (?Oligostegina) and fragments of Hedbergella - type planktonic foraminifera.

2. Globotruncana renzi (Gandolfi). Assemblage zone A. Beer, South east Devon. (x 130). Clear development of two keels in juvenile stages, reduced to one keel in the final chamber.

PLATE 10.

Globigerinacea, Orbitoidacea.

1. Whiteinella baltica Douglas and Rankin. Umbilical view.
Assemblage zone A. South east Kent. × 125.

2. Whiteinella baltica Douglas and Rankin. Spiral view.
Assemblage zone B. South east Kent. × 80.

3. Whiteinella baltica Douglas and Rankin. Umbilical view.
Topotype. Bavnodde greensand Bornholm, Denmark. × 55.

4. Whiteinella baltica Douglas and Rankin. Spiral view.
Topotype. Bavnodde greensand Bornholm, Denmark. × 55.

5. Archeoglobigerina bosquensis Pessagno. Side view.
Assemblage zone B. South east Kent. × 60.

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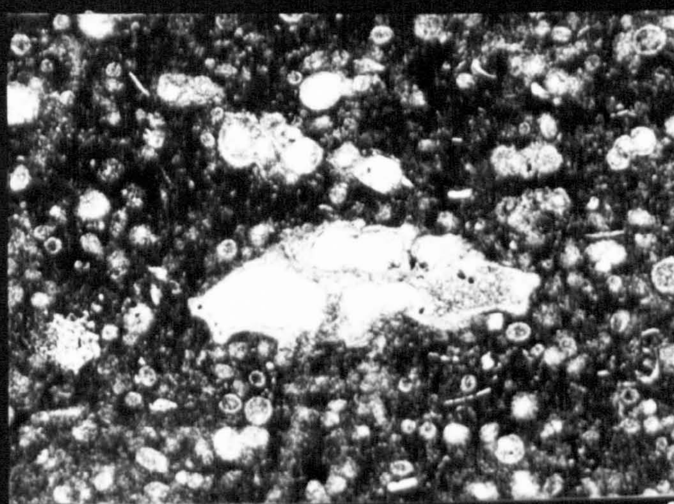

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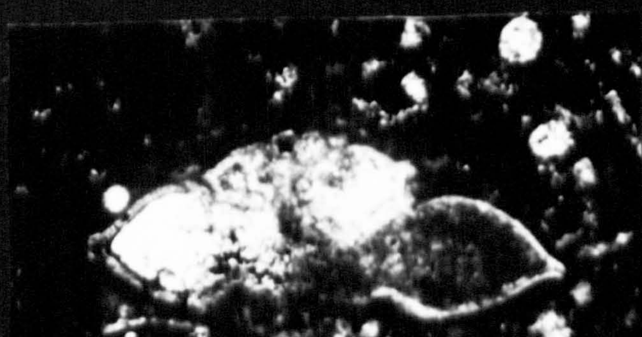

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6. Archeoglobigerina bosquensis Pessagno. Umbilical view. Assemblage zone B. South east Kent. x 85.

7. Eponides cf. concinna Brotzen. Spiral view. Assemblage zone E. Freshwater Bay, Isle of Wight. x 80.

8. Eponides cf. concinna Brotzen. Umbilical view. Assemblage zone E. Freshwater Bay, Isle of Wight. x 80.

9. Cibicides beaumontianus. (d'Orbigny). Sporal view. Assemblage zone F. Culver Cliff, Isle of Wight. x 85.

10. Cibicides beaumontianus (d'Orbigny). Umbilical view. Assemblage zone F. Culver Cliff, Isle of Wight. x 75.

11. Cibicides beaumontianus (d'Orbigny). Side view. Assemblage zone F. Culver Cliff, Isle of Wight. x 90.

12. Cibicides beaumontianus (d'Orbigny). var. A. Spiral view. Assemblage zone E. South east Kent. x 85.

13. Cibicides beaumontianus (d'Orbigny). var. A. Umbilical view. Assemblage zone E. South east Kent. x 85.

PLATE 11.

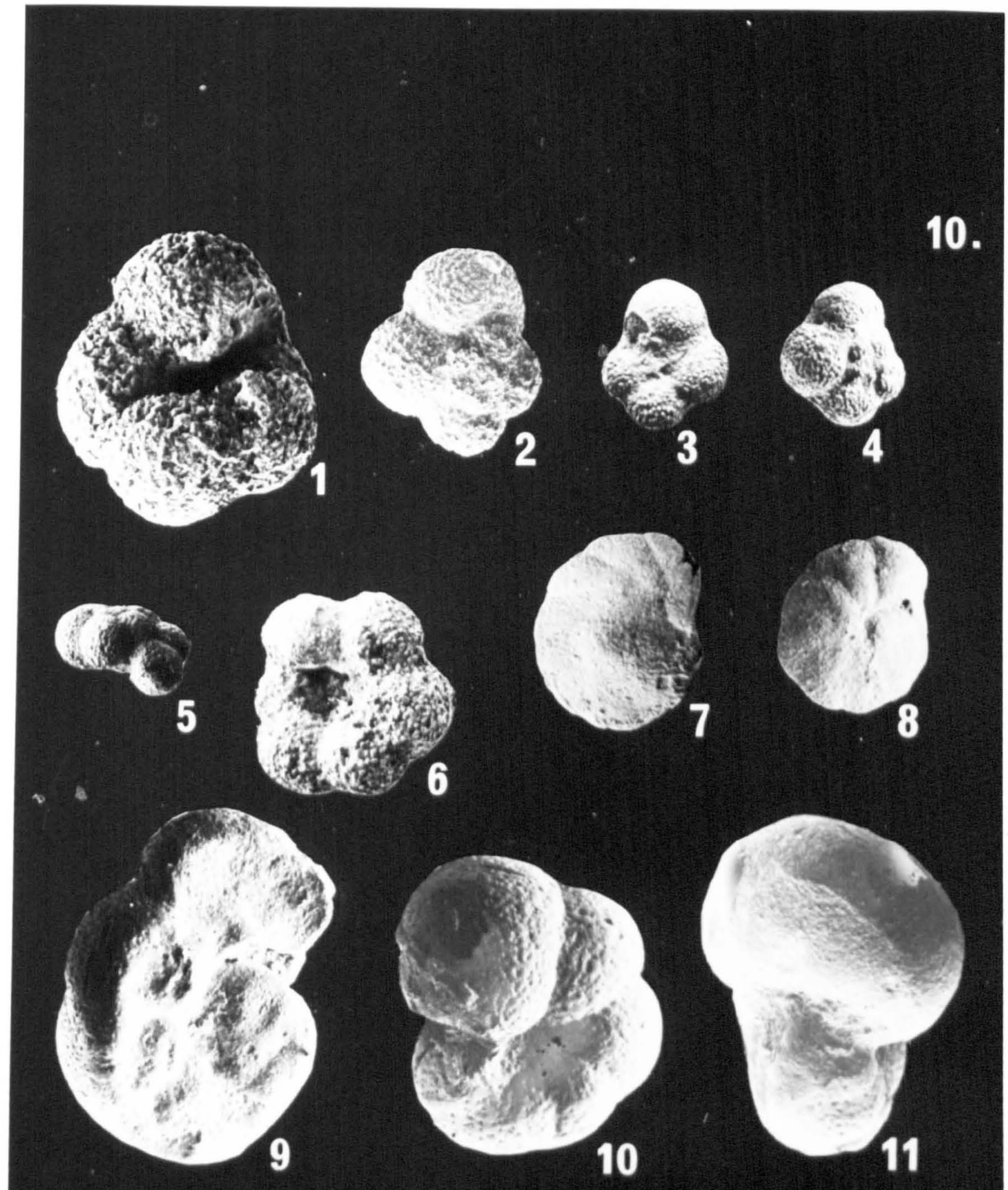
Orbitoidacea, Cassidulinacea.

1. Cibicides ribbingi Brotzen. Umbilical view. Assemblage zone E. South east Kent. x 80.

2. Cibicides ribbingi Brotzen. Spiral view. Assemblage zone E. South east Kent. x 80.

3. Cibicides ribbingi Brotzen. Side view. Assemblage zone E. South east Kent. x 80.

4. Cibicides sp. A. Umbilical view. Assemblage zone D. Freshwater Bay, Isle of Wight. x 175.



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5. Cibicides sp. A. Spiral view. Assemblage zone D. Freshwater Bay, Isle of Wight. x 175.

6. Pleurostomella subnodosus Reuss. Side view. Assemblage zone C. Newton-by-Castleacre, Norfolk. x 40.

7. Pleurostomella subnodosus Reuss. Apertural view. Assemblage zone C. Newton-by-Castleacre, Norfolk. x 40.

8. Ellipsoidella pleurostomelloides Heron-Allen and Earland, Assemblage zone D. Quidhampton, Wiltshire. x 60.

9. Enlargement of aperture in E. pleurostomelloides. (Fig. 8). x 300.

10. Cassidella sp.A. Assemblage zone F. Culver Cliff, Isle of Wight. x 180.

11. Loxostomum eleyi (Cushman). Assemblage zone C. B.H. No. 25. Thames Barrier Site Investigation. x 180.

12. Loxostomum eleyi (Cushman). Side view. Assemblage zone C. B.H. No. 25. Thames Barrier Site Investigation. x 80.

13. Quadrimorphina allomorphinoides (Reuss). Spiral view. Assemblage zone A. B.H. No. 25. Thames Barrier Site Investigation. x 75.

14. Quadrimorphina allomorphinoides (Reuss). Umbilical view. Assemblage zone A. South east Kent. x 75.

15. Quadrimorphina trochoides (Reuss). Umbilical view. Assemblage zone E. Quidhampton, Wiltshire. x 75.

16. Quadrimorphina trochoides (Reuss). Side view. Assemblage zone E. Quidhampton, Wiltshire. x 65.

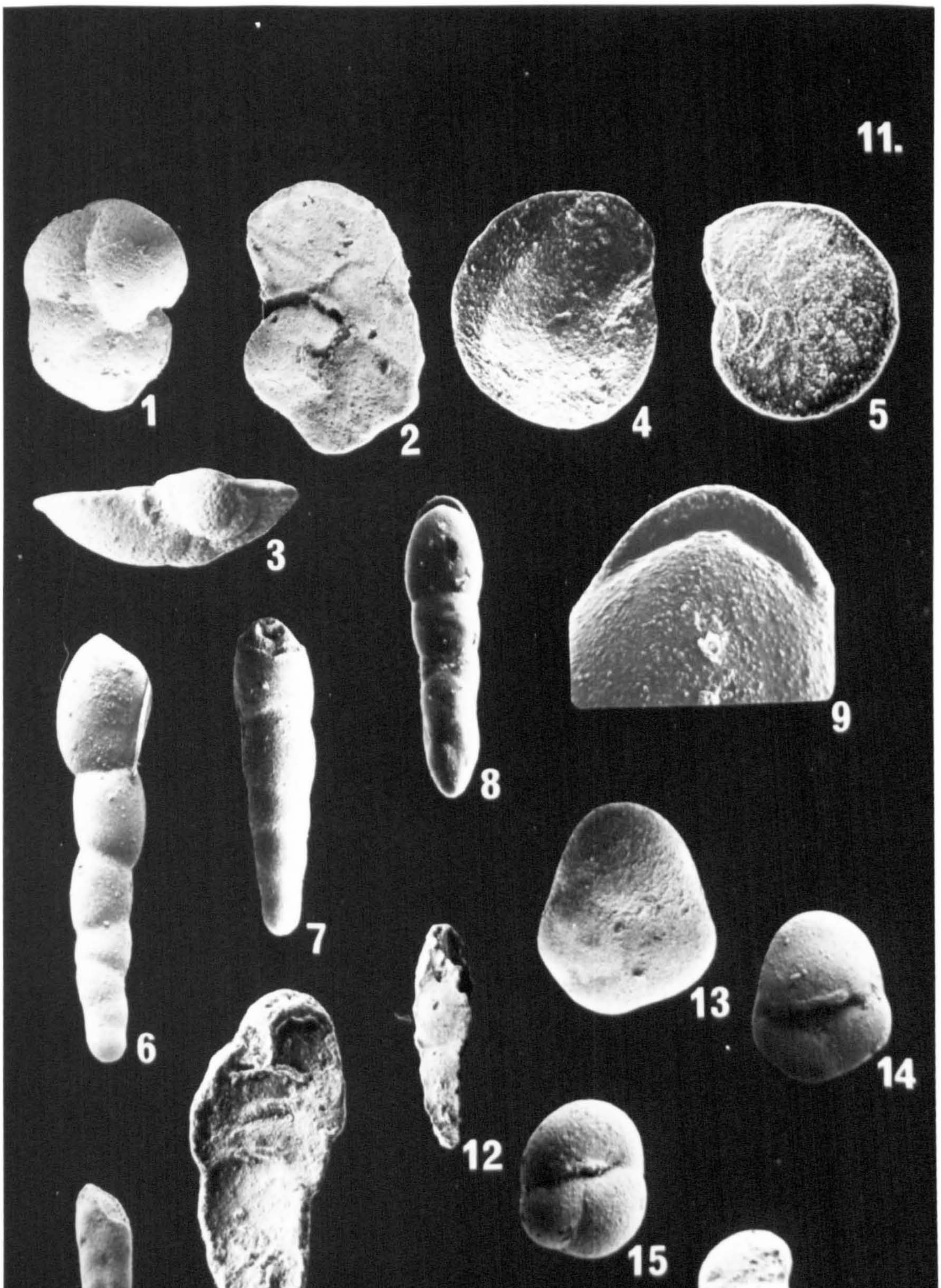
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PLATE 12.

Cassidulinacea.

1. Osangularia whitei var. whitei (Brotzen). Umbilical view. Assemblage zone C. South east Kent. x 80.
2. Osangularia whitei var. whitei (Brotzen). Spiral view. Assemblage zone D. Freshwater Bay, Isle of Wight. x 80.
3. Osangularia whitei var. whitei (Brotzen). Side view. Assemblage zone C. South east Kent. x 80.
4. Globorotalites cushmani Goel. Side view. Assemblage zone A. South east Kent. x 90.
5. Globorotalites cushmani Goel. Umbilical view. Assemblage zone C. Freshwater Bay, Isle of Wight. x 70.
6. Gyroidinoides nitidus (Reuss). Side view. Assemblage zone C. B.H. No. 25. Thames Barrier Site Investigation x 85.
7. Gyroidinoides nitidus (Reuss). Spiral view. Assemblage zone A. Beer, South east Devon. x 75.
8. Gyroidinoides nitidus (Reuss). Umbilical view. Assemblage zone C. B.H. No. 25. Thames Barrier Site Investigation. x 80.
9. Gavelinella ammonoides (Reuss). Spiral view. Assemblage zone B. South east Kent. x 80.
10. Gavelinella ammonoides (Reuss). Umbilical view. Assemblage zone B. South east Kent. x 80.
11. Gavelinella ammonoides (Reuss). Side view. Assemblage zone C. South east Kent. x 75.

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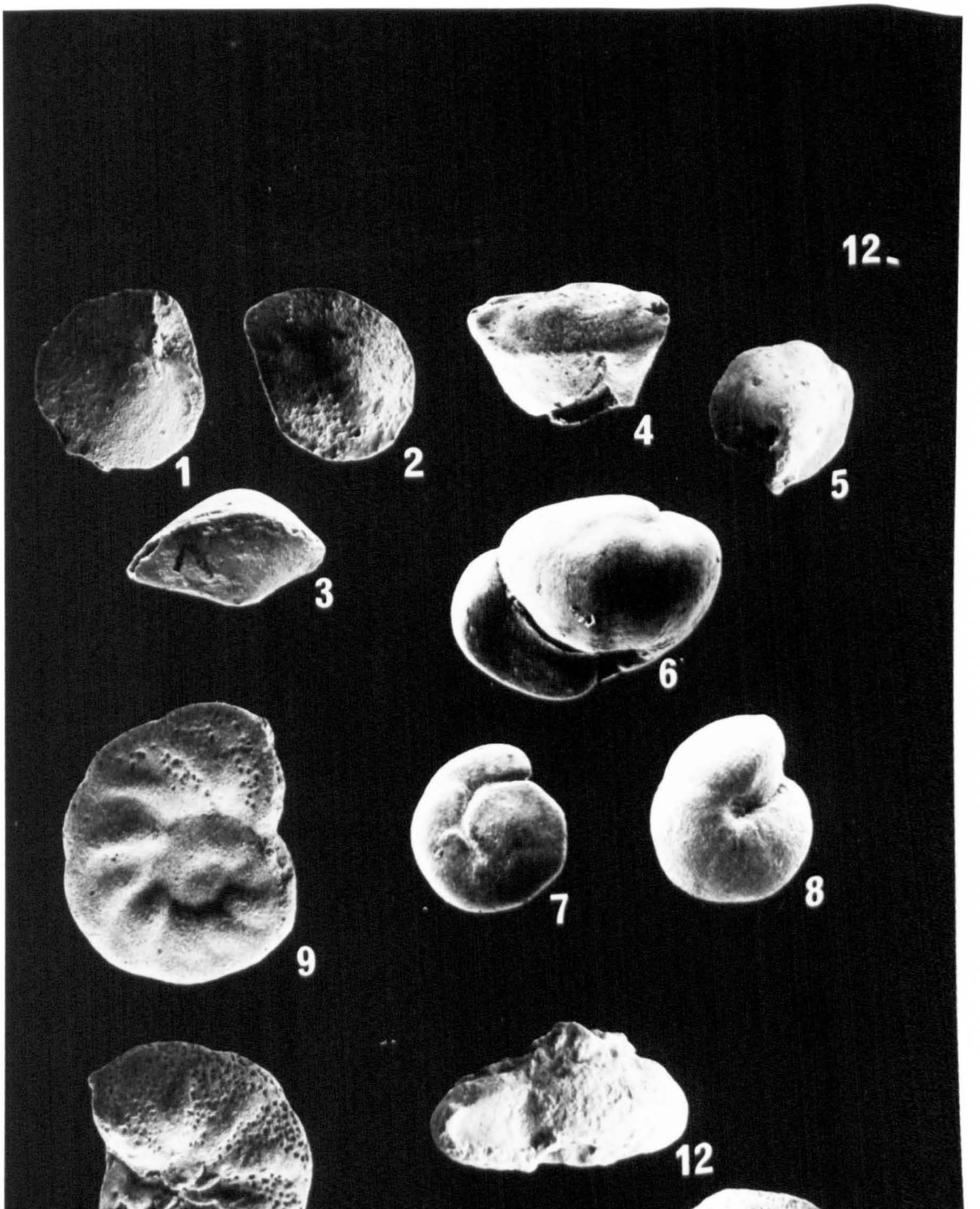


12. Gavelinella cf. clementiana (d'Orbigny). Side view. Assemblage zone F. Culver Cliff, Isle of Wight. x 75.

13. Gavelinella cf. clementiana (d'Orbigny). Spiral view. Assemblage zone F. Culver Cliff, Isle of Wight. x 65.

14. Gavelinella cf. clementiana (d'Orbigny). Umbilical view. Assemblage zone F. Culver Cliff, Isle of Wight. x 75.

PLATE 13.

Cassidulinacea.

1. Gavelinella pertusa (Marsson). Umbilical view. Assemblage zone A. B.H. No. 25. Thames Barrier Site Investigation. x 95.

2. Gavelinella pertusa (Marsson). Spiral view. Assemblage zone B. South east Kent. x 60.

3. Gavelinella thalmanni (Brotzen). Umbilical view. Assemblage zone C. Newton-by-Castleacre, Norfolk. x 80.

4. Gavelinella thalmanni (Brotzen). Spiral view. Assemblage zone B. South east Kent. x 80.

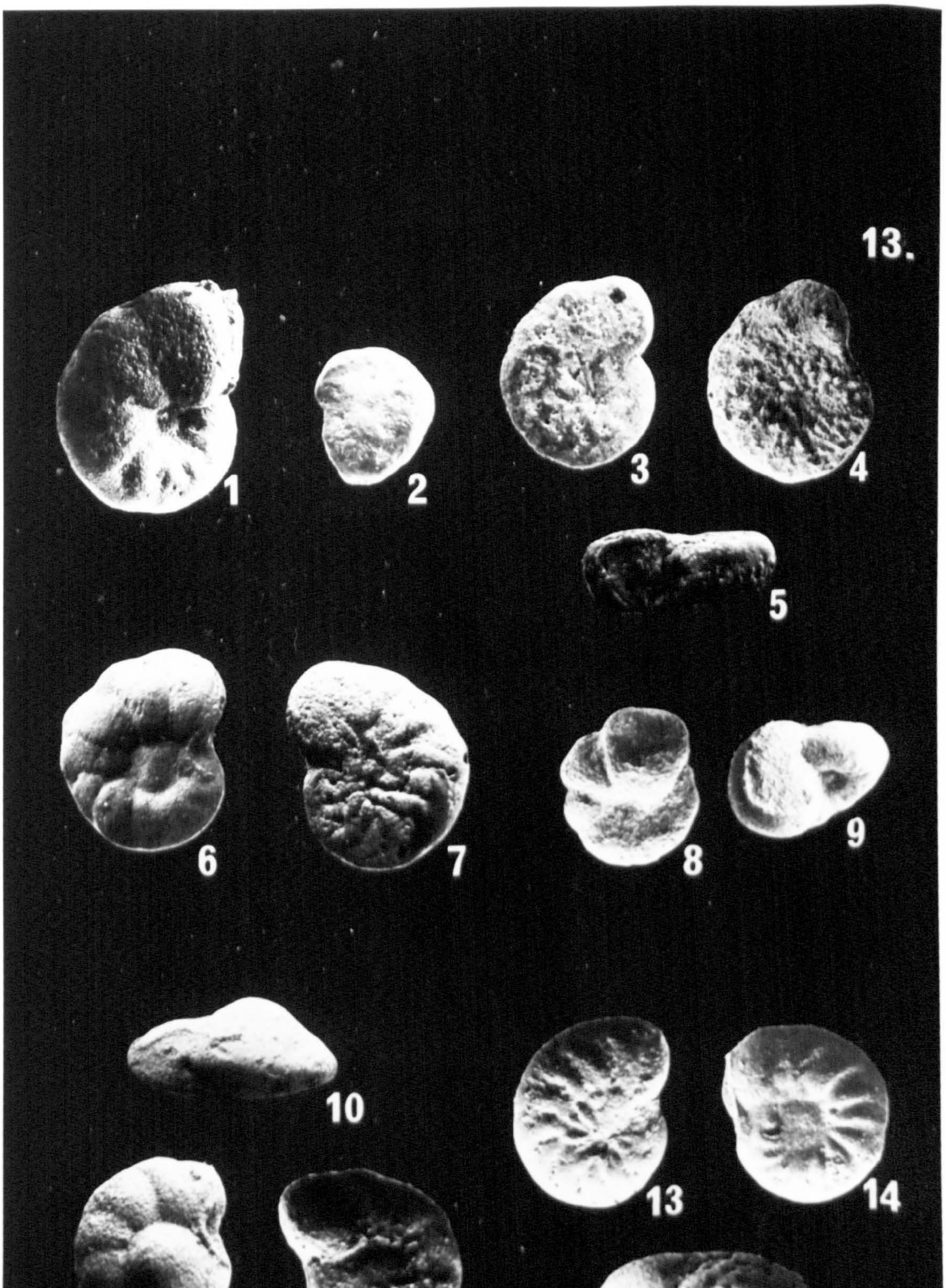
5. Gavelinella thalmanni (Brotzen). Side view. Assemblage zone D. Culver Cliff, Isle of Wight. x 80.

6. Gavelinella sp. A. Spiral view. Assemblage zone F. Culver Cliff, Isle of Wight. x 90.

7. Gavelinella sp. A. Umbilical view. Assemblage zone F. Culver Cliff, Isle of Wight. x 90.

8. Gavelinella tumida Brotzen. Umbilical view. Assemblage zone E. South east Kent. x 80.

9. Gavelinella tumida Brotzen. Side view. Assemblage zone D. B.H. No. 25. Thames Barrier Site Investigation. x 80.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10. <u>Gavelinella</u> sp. B. Side view. Assemblage zone A. South east Kent. x 80.

11. <u>Gavelinella</u> sp. B. Spiral view. Assemblage zone A. South east Kent. x 80.

12. <u>Gavelinella</u> sp. B. Umbilical view. Assemblage zone A. South east Kent. x 80.

13. <u>Gavelinella</u> sp. C. Umbilical view. Assemblage zone A. Beer, South east Devon. x 75.

14. <u>Gavelinella</u> sp. C. Spiral view. Assemblage zone A. Beer, South east Devon. x 75.

15. <u>Gavelinella</u> sp. C. Side view. Assemblage zone A. Beer, South east Devon. x 75.

<u>PLATE 14.</u>

<u>Cassidulinacea</u>.

1. <u>Lingulogavelinella</u> sp. A. Umbilical view. Assemblage zone D. B.H. No. 25. Thames Barrier Site Investigation. x 80.

2. <u>Lingulogavelinella</u> sp. A. Spiral view. Assemblage zone C. B.H. No. 25. Thames Barrier Site Investigation. x 65.

3. <u>Lingulogavelinella</u> sp. A. Side view. Assemblage zone D. B.H. No. 25. Thames Barrier Site Investigation. x 80.

4. <u>Stensioina exsculpta exsculpta</u> (Reuss). Umbilical view. Assemblage zone E. South east Kent. x 80.

5. <u>Stensioina exsculpta exsculpta</u> (Reuss). Side view. Assemblage zone D. Quidhampton, Wiltshire. x 80.

6. <u>Stensioina exsculpta exsculpta</u> (Reuss). Spiral view. Assemblage zone D. Quidhampton, Wiltshire. x 80.

7. Stensioina exsculpta gracilis Brotzen. Umbilical view. Assemblage zone F. Witham, Essex. x 60.

8. Stensioina exsculpta gracilis Brotzen. Side view. Assemblage zone F. Witham, Essex. x 65.

9. Stensioina granulata (Olbertz). Spiral view. Assemblage zone B. South east Kent. x 75.

10. Stensioina granulata (Olbertz). Umbilical view. Assemblage zone B. South east Kent. x 80.

11. Stensioina granulata (Olbertz). Side view. Assemblage zone B. South east Kent. x 80.

12. Stensioina granulata (Olbertz). Spiral view. Assemblage zone C. South east Kent. x 80.

13. Stensioina granulata (Olbertz) var. A. Side view. Assemblage zone D. Quidhampton, Wiltshire. x 80.

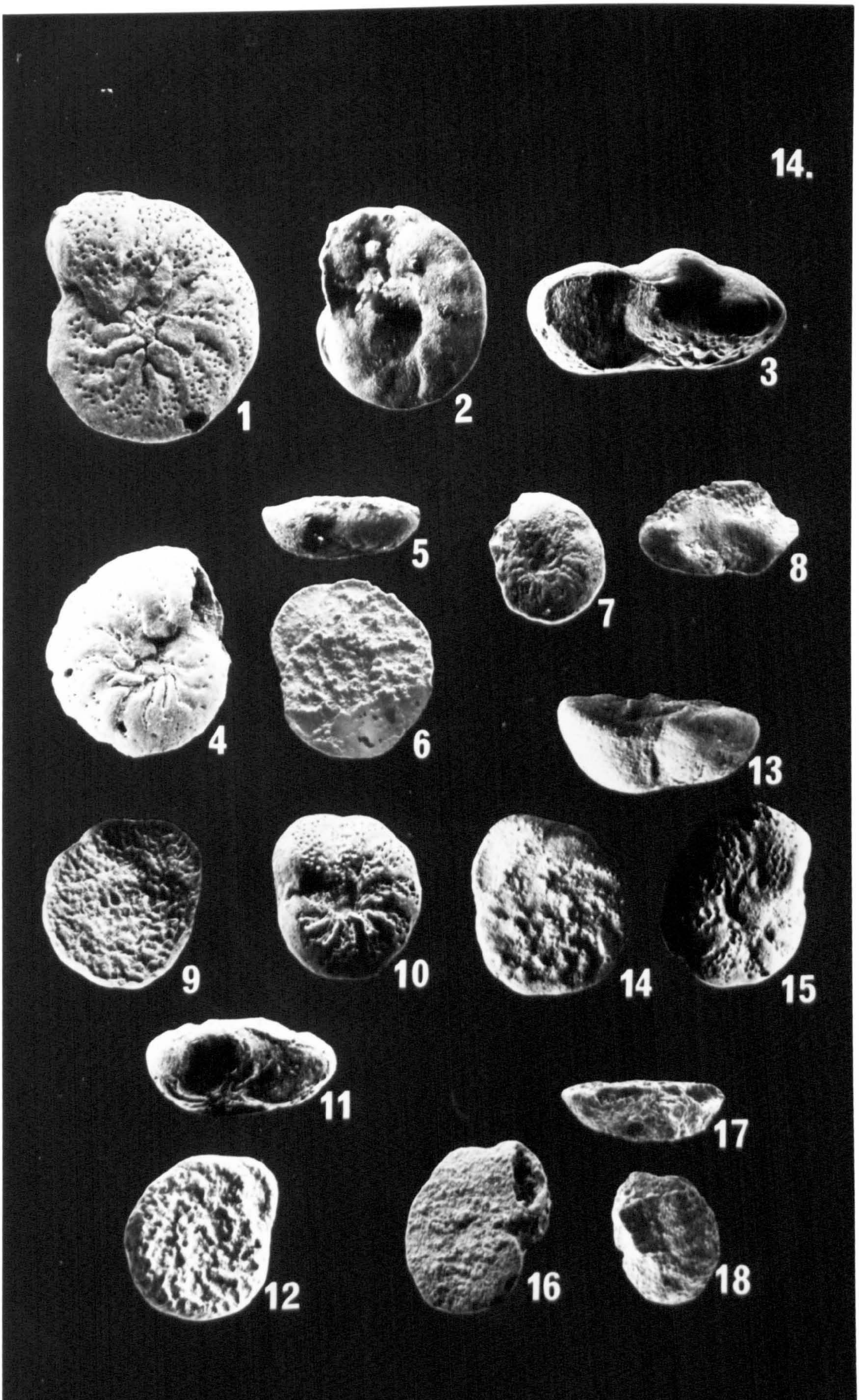
14. Stensioina granulata (Olbertz) var. A. Spiral view. Assemblage zone D. Quidhampton, Wiltshire. x 80.

15. Stensioina granulata (Olbertz) var. A. Umbilical view. Assemblage zone D. Quidhampton, Wiltshire. x 80.

16. Stensioina sp. A. Spiral view. Assemblage zone A. South east Kent. x 75.

17. Stensioina sp. A. Side view. Assemblage zone A. South east Kent. x 70.

18. Stensioina sp. A. Umbilical view. Assemblage zone A South east Kent. x 60.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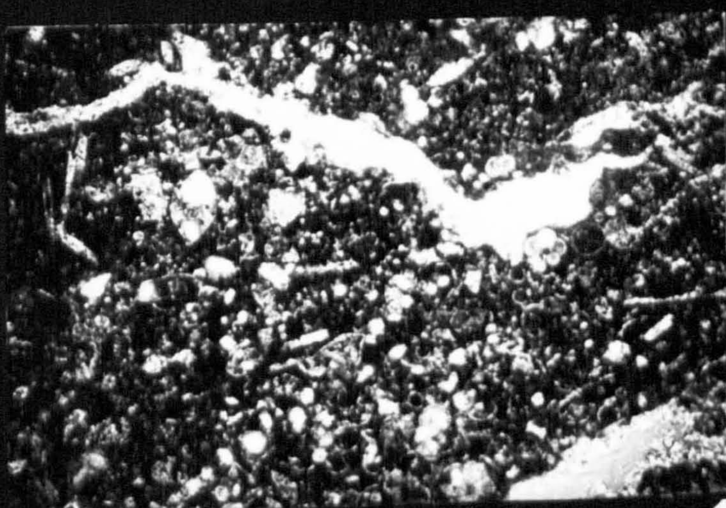

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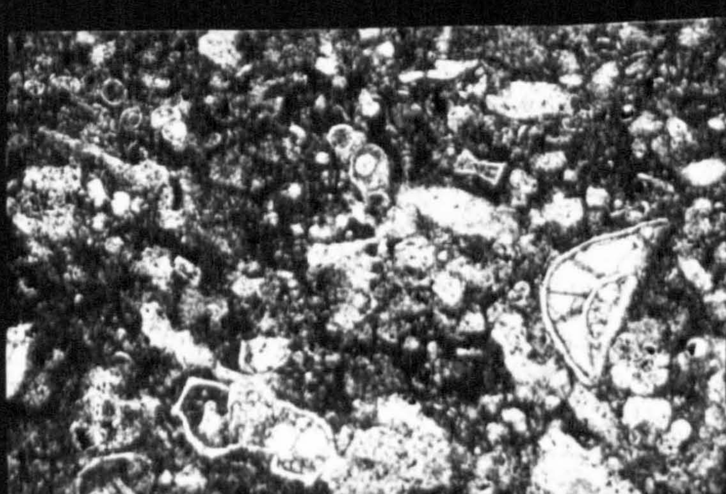

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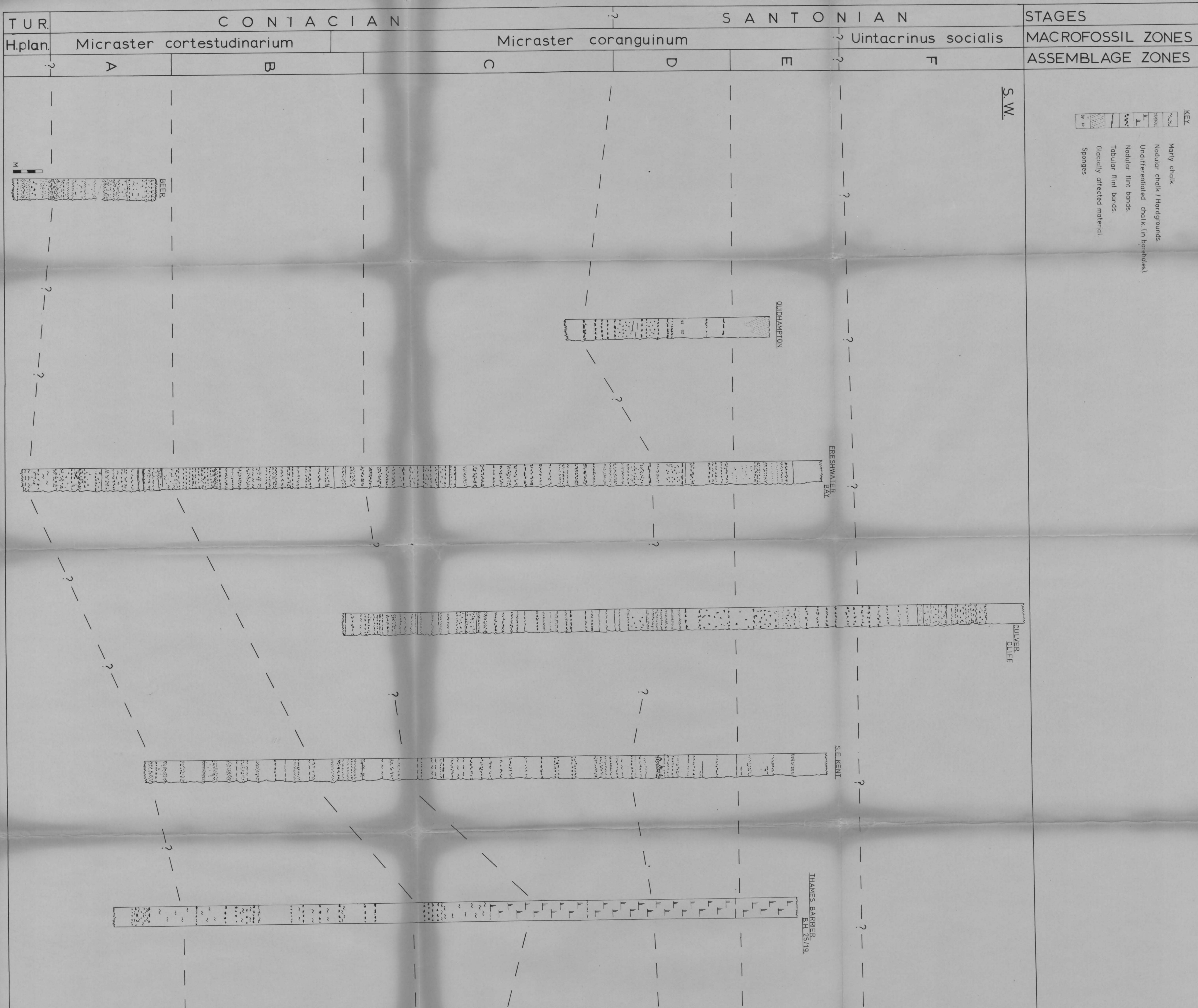
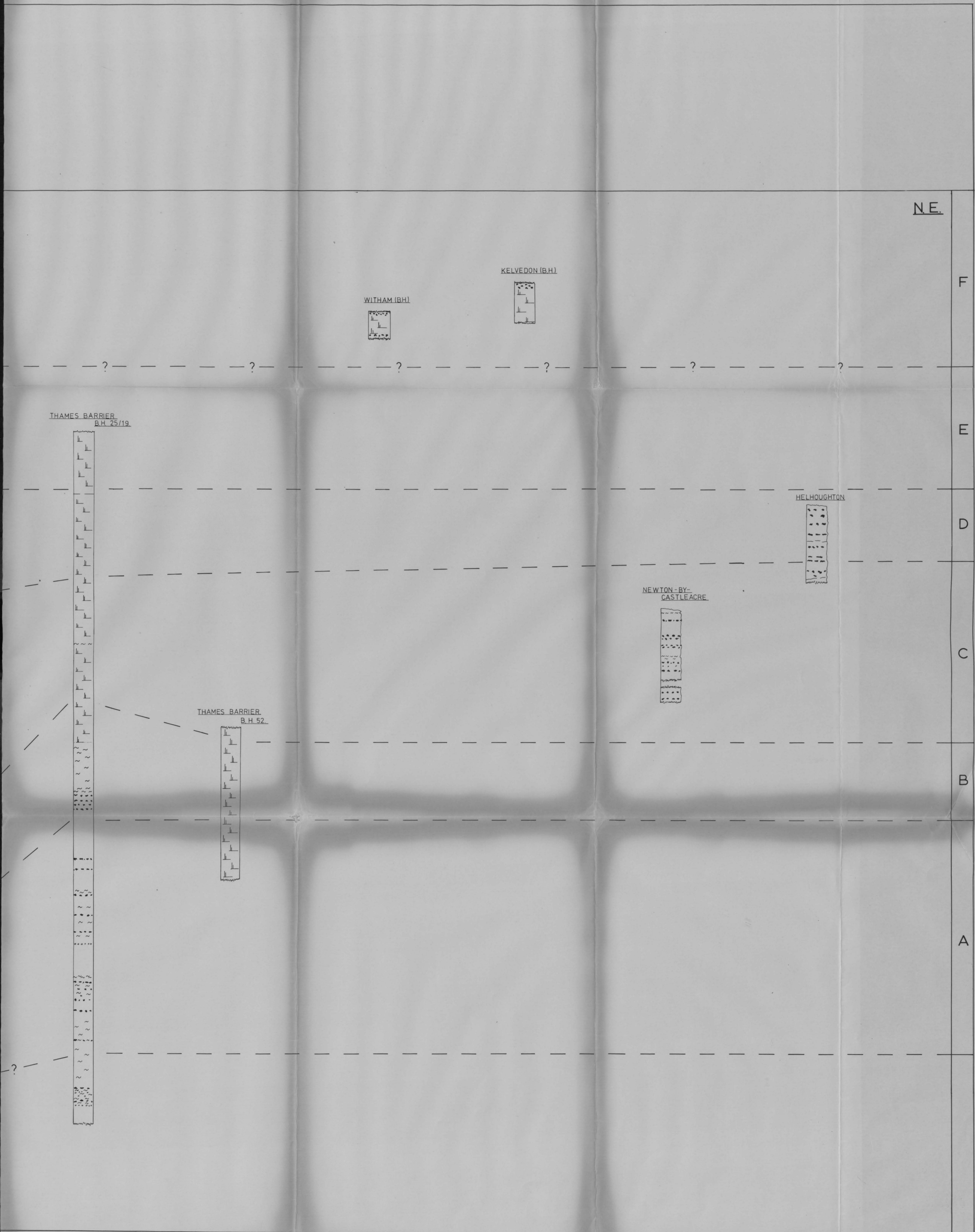
ENCLOSURE 4: FRESHWATER BAY, ISLE OF WIGHT

ENCLOSURE 1: CORRELATION OF LOWER SENONIAN SECTIONS ACROSS SOUTHERN ENGLAND.

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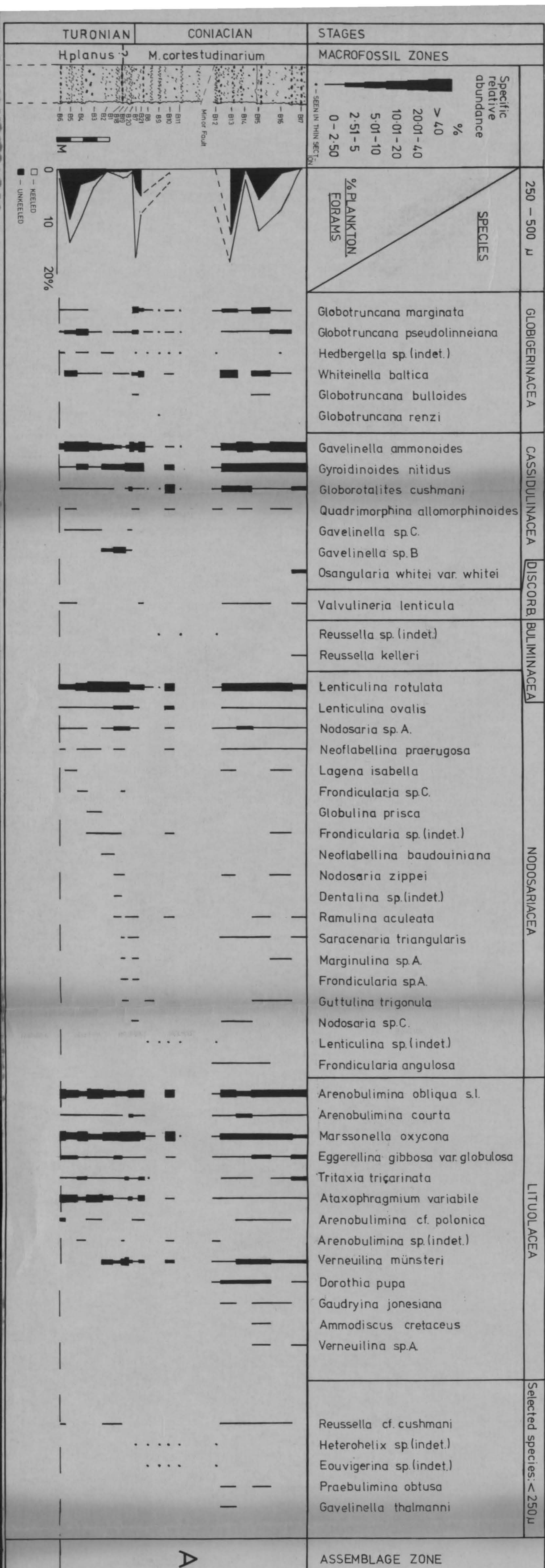
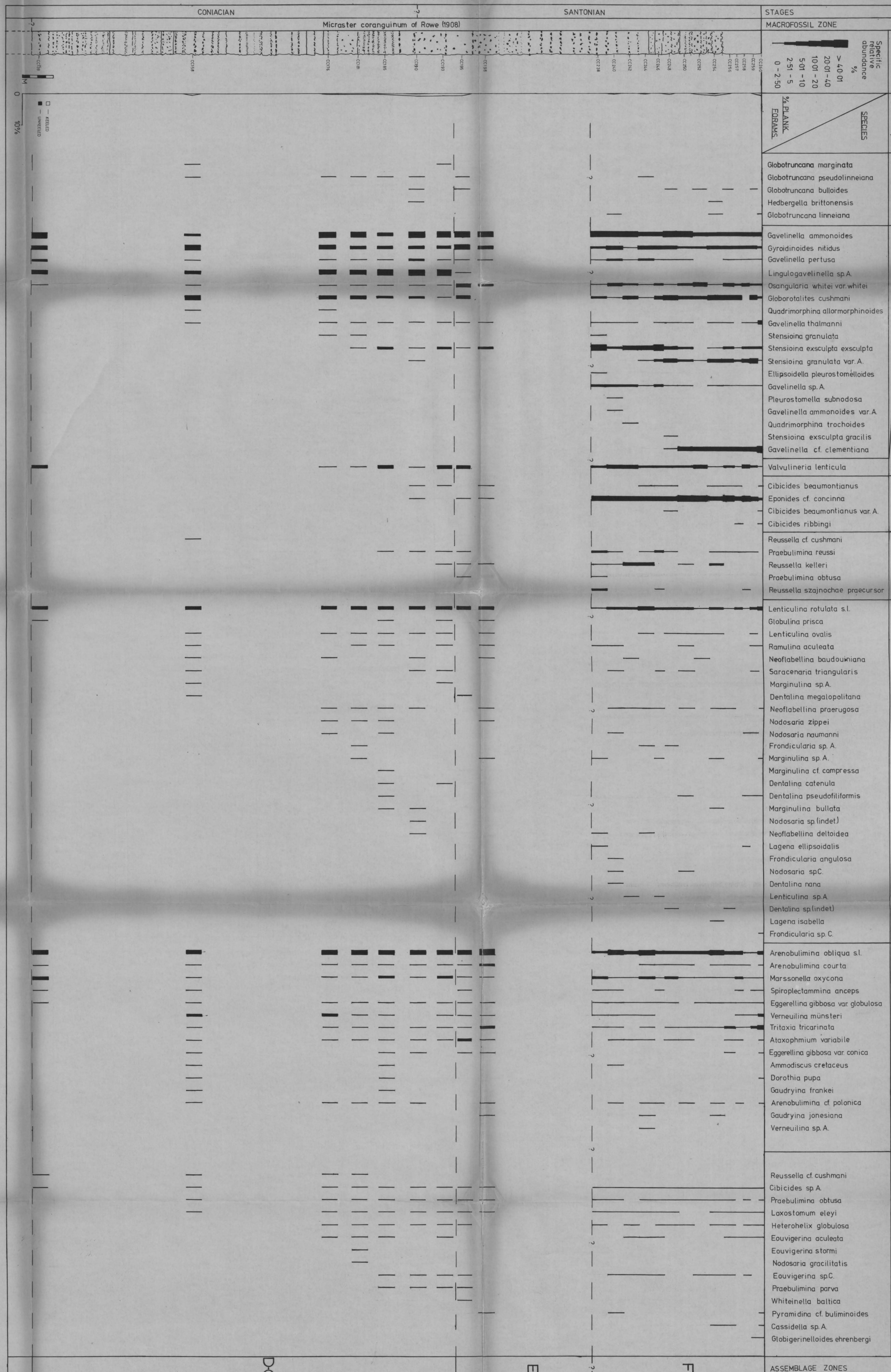
A



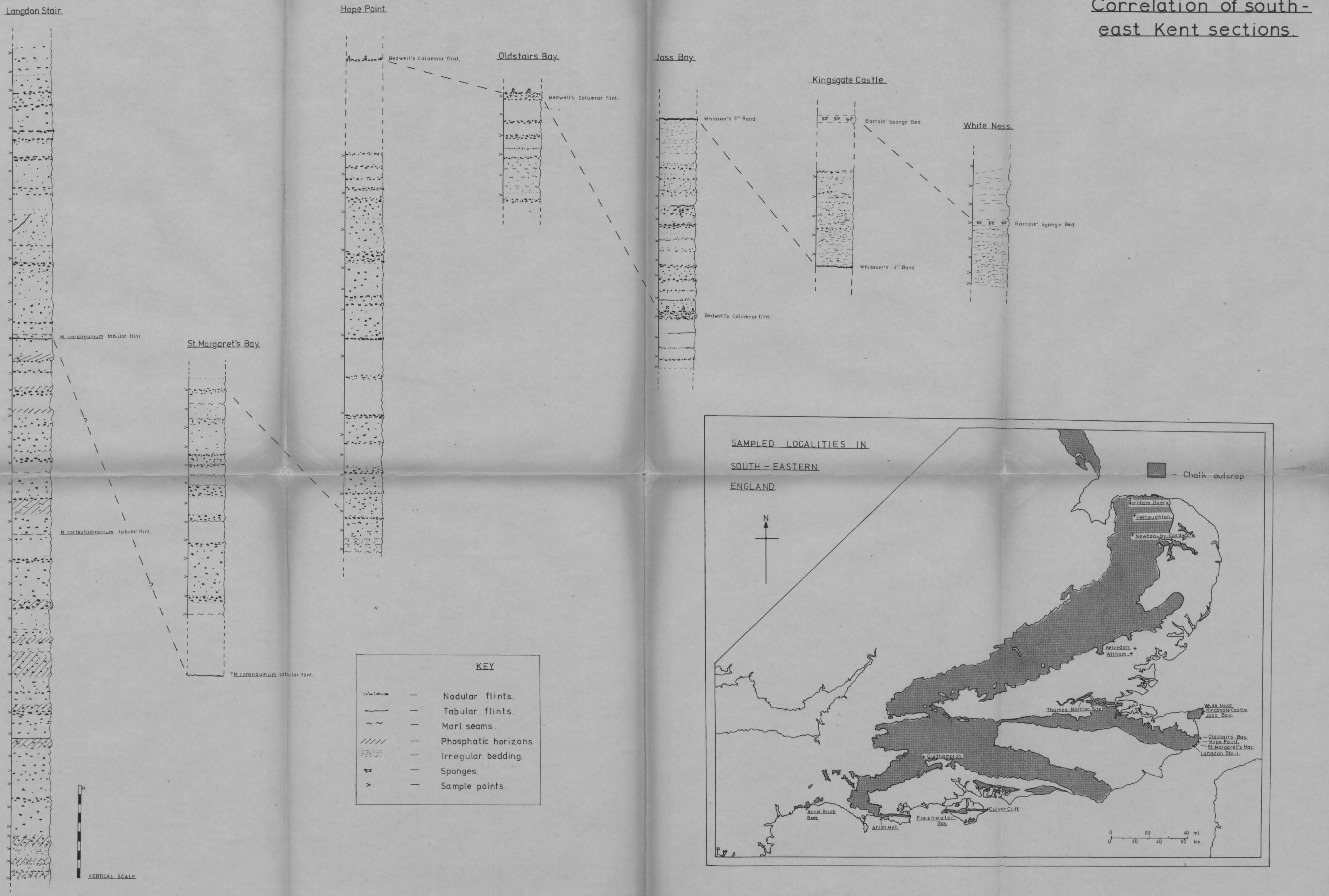
6(b): BEER, SOUTH EAST DEVON.



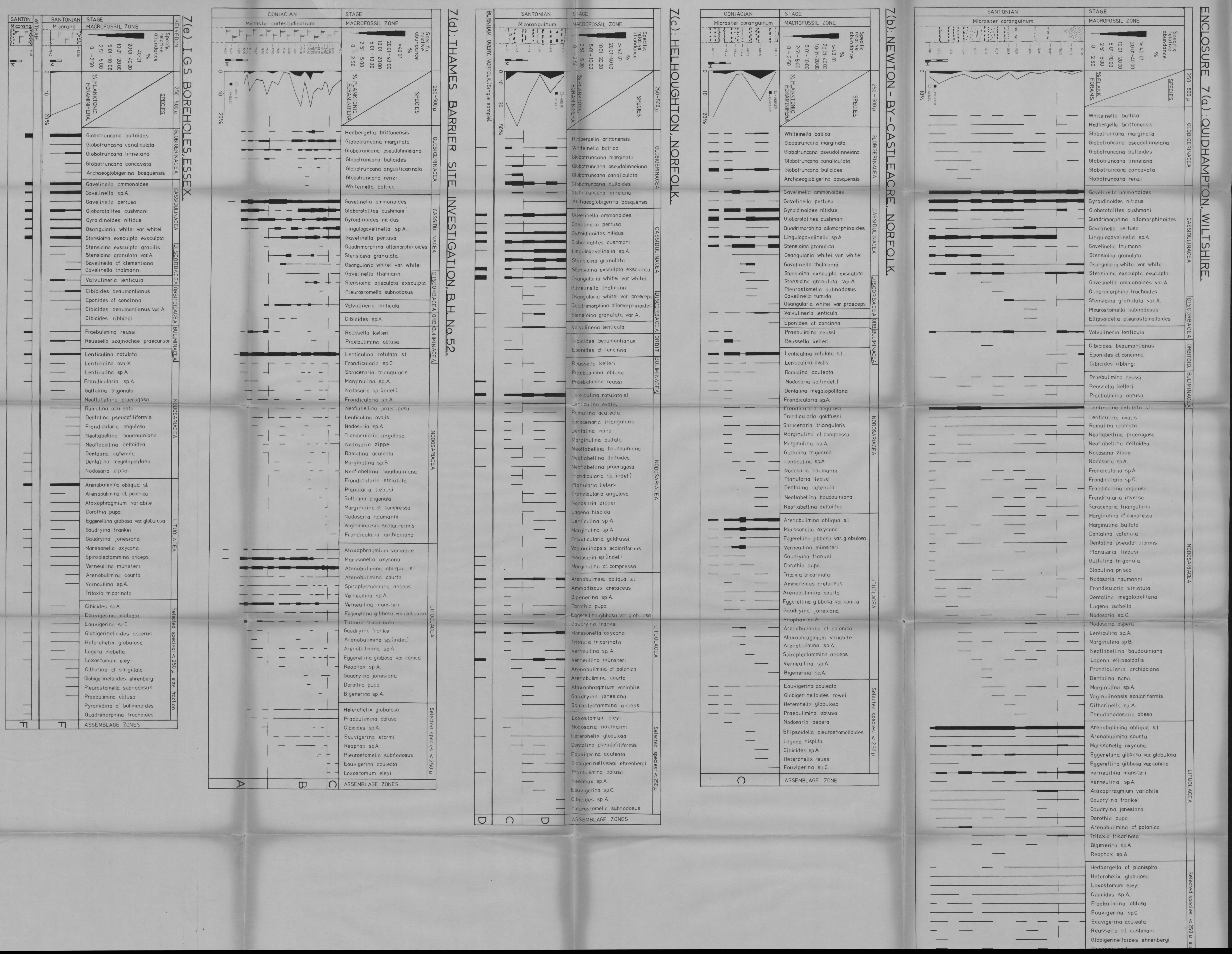
ENGLEBOURNE ... CULVER CLIFF, ISLE OF WIGHT

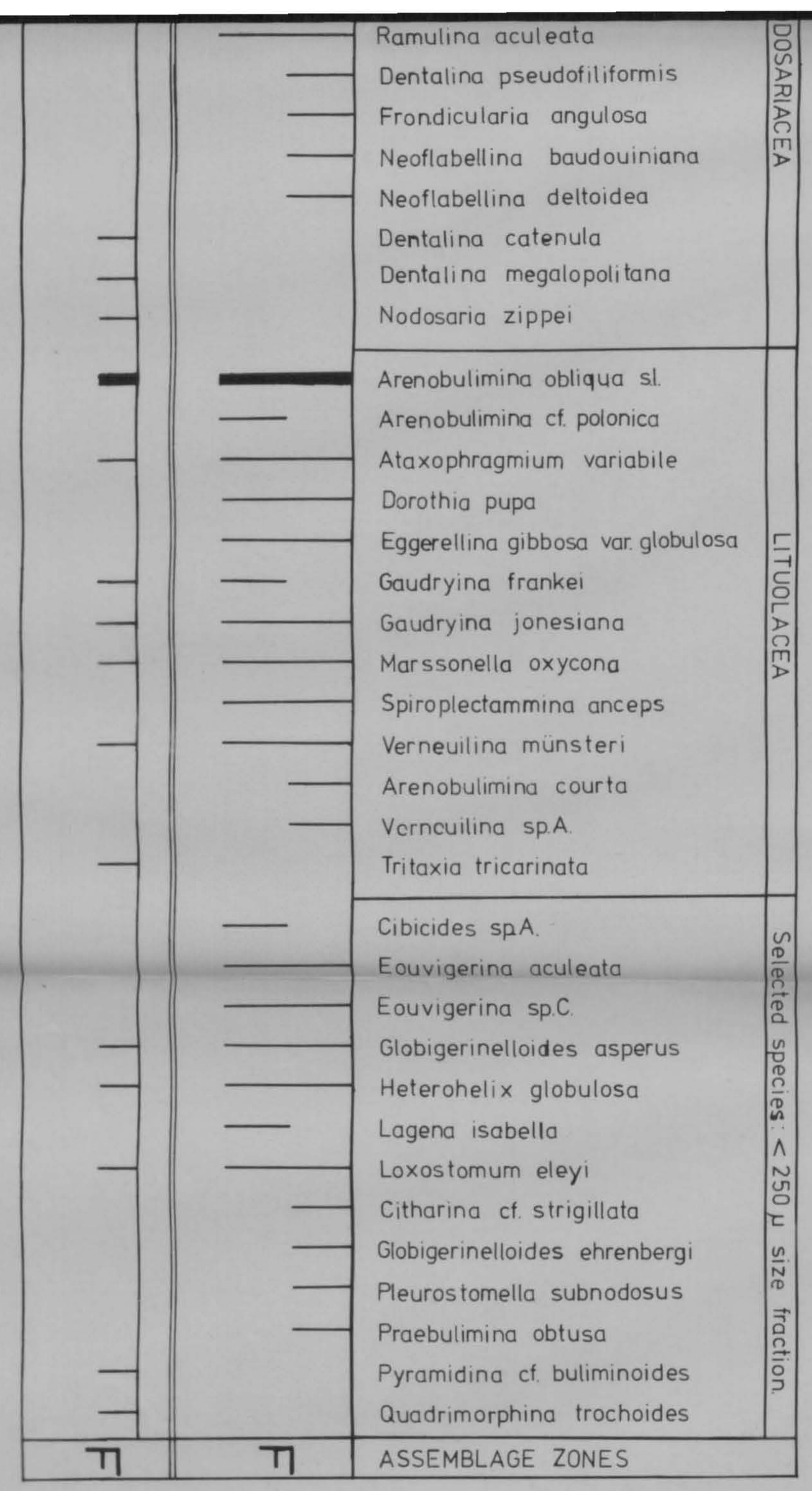
ENCLOSURE 2.

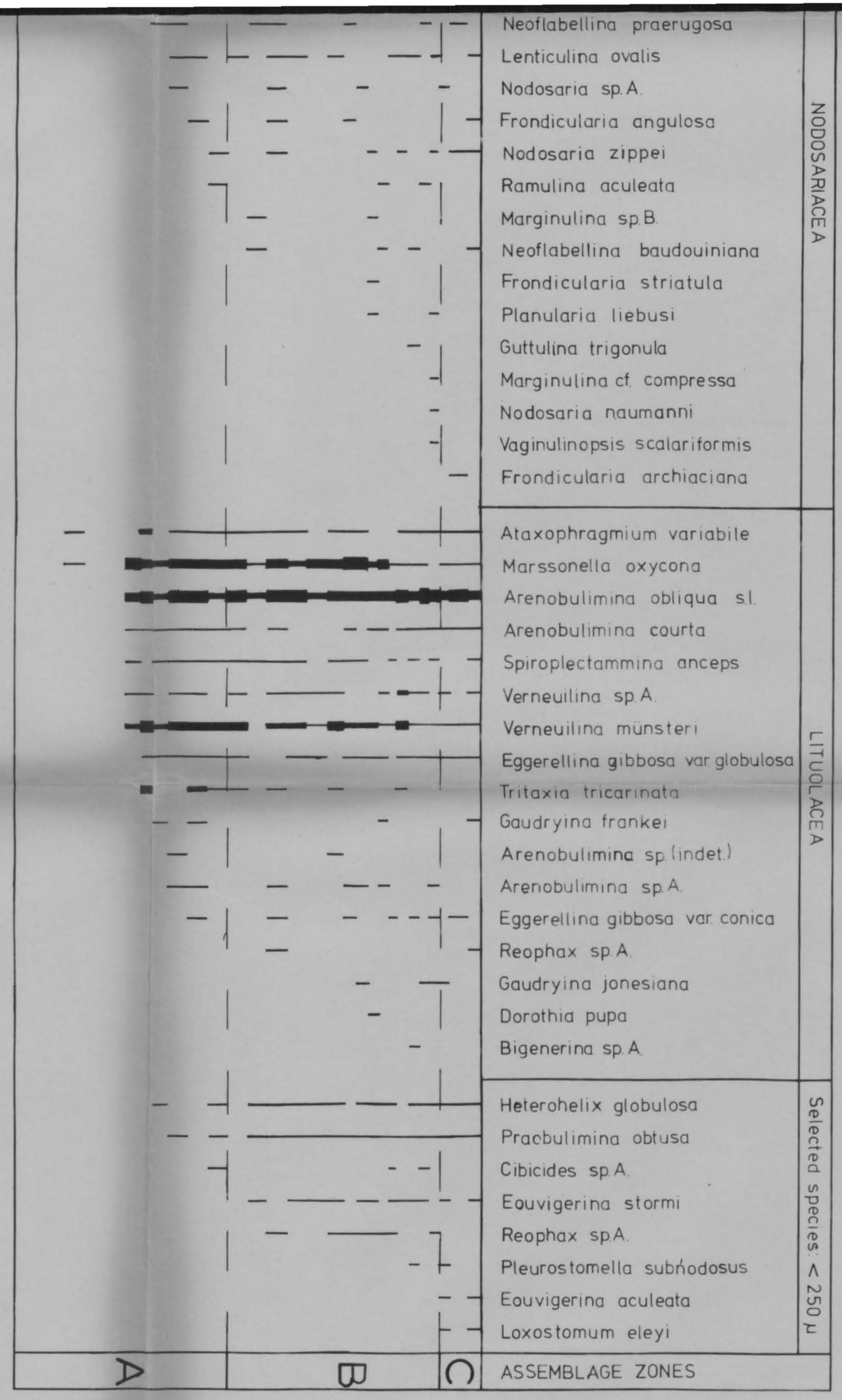
Correlation of south-east Kent sections.

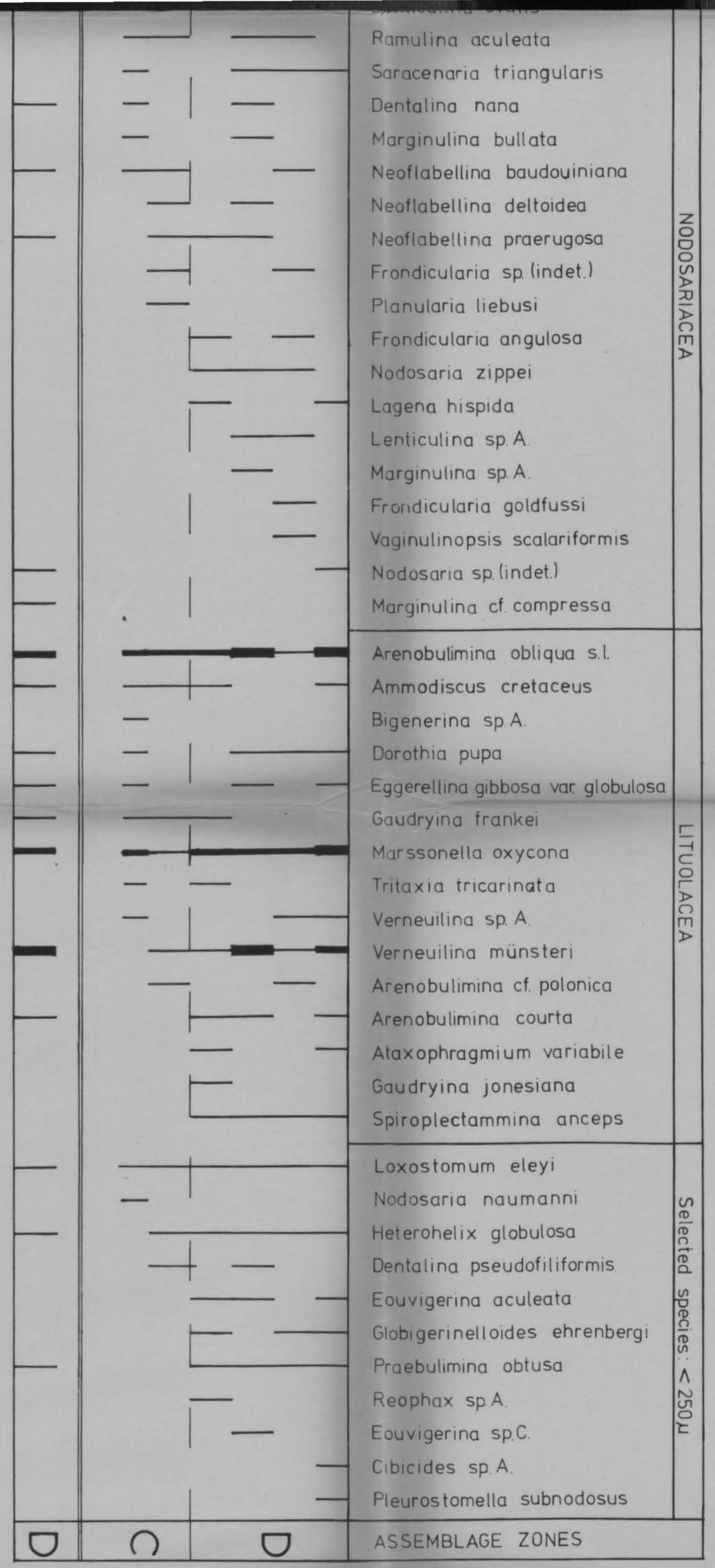


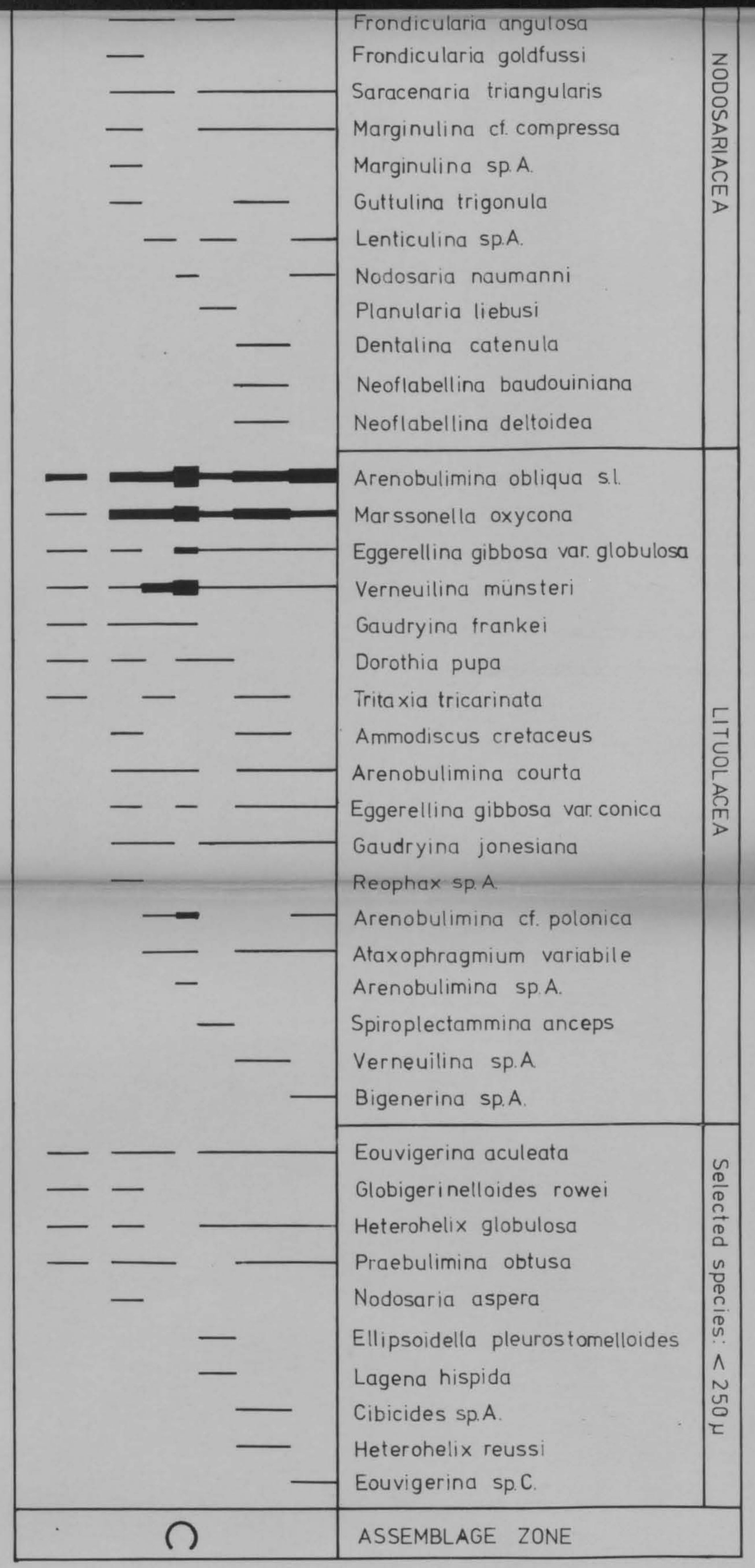
ENCLOSURE 3: SOUTH EAST KENT.

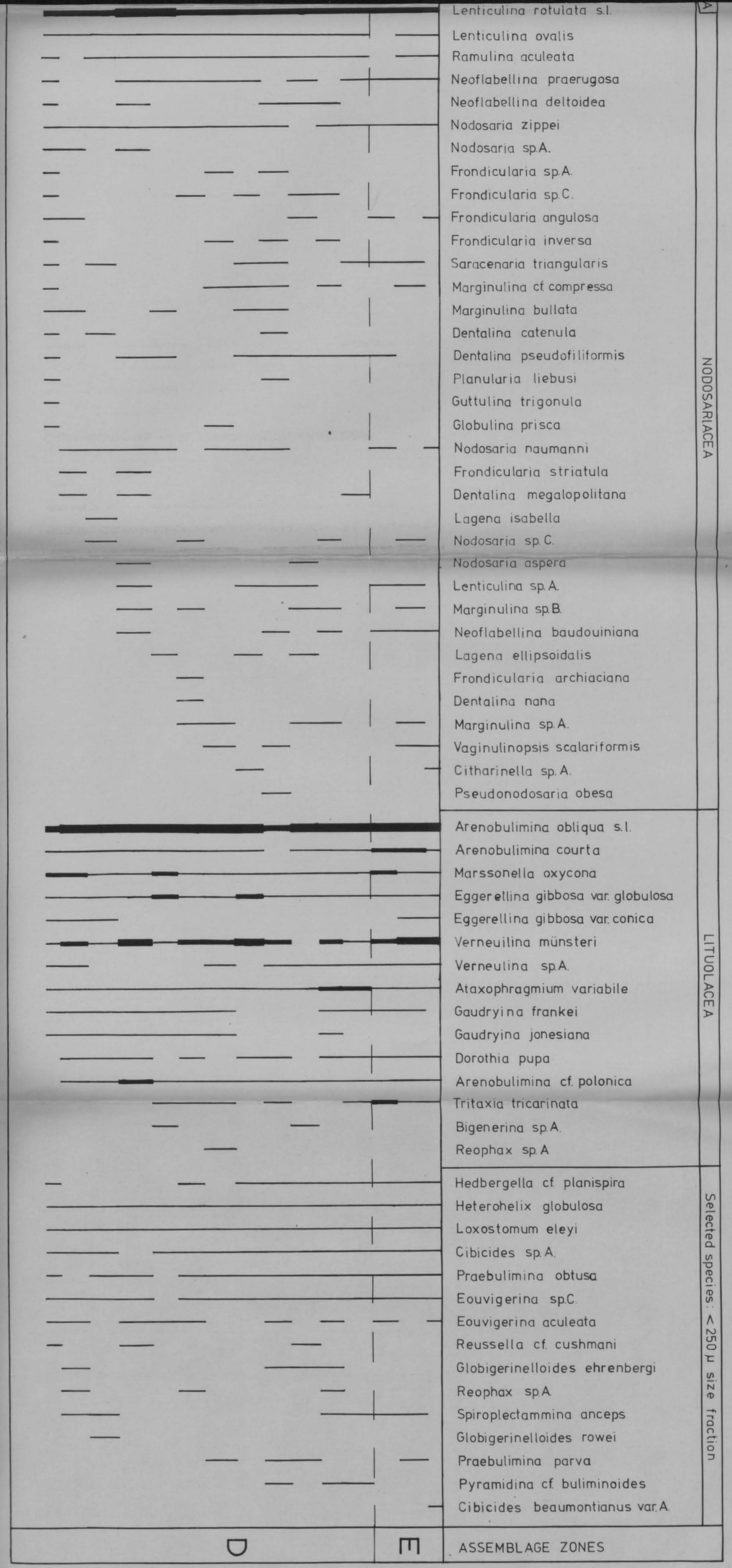

ENCLOSURE 7(a): QUIDHAMPTON, WILTSHIRE.
STAGE
SANTONIAN
MACROFOSSIL ZONE
Micraster coranguinum
Specific relative abundance %
>40.01
20.01-40.00
10.01-20.00
5.01-10.00
2.51-5.00
0-2.50
% PLANK. FORAMS.
SPECIES
250-500 µ
GLOBIGERINACEA
Whiteinella baltica
Hedbergella brittonensis
Globotruncana marginata
Globotruncana pseudolinneiana
Globotruncana bulloides
Globotruncana linneiana
Globotruncana concavata
Globotruncana renzi
CASSIDULINACEA
Gavelinella ammonoides
Gyroidinoides nitidus
Globorotalites cushmani
Quadrimorphina allomorphinoides
Gavelinella pertusa
Lingulogavelinella sp.A
Gavelinella thalmanni
Stensioina granulata
Osangularia whitei var. whitei
Stensioina exsculpta exsculpta
Gavelinella ammonoides var.A
Quadrimorphina trochoides
Stensioina granulata var.A
Pleurostomella subnodosus
Ellipsoidella pleurostomelloides
DISCORBACEA
Valvulineria lenticula
ORBITOID
Cibicides beaumontianus
Eponides cf. concinna
Cibicides ribbingi
BULIMINACEA
Praebulimina reussi
Reussella kelleri
Praebulimina obtusa
NODOSARIACEA
Lenticulina rotulata s.l.
Lenticulina ovalis
Ramulina aculeata
Neoflabellina praerugosa
Neoflabellina deltoidea
Nodosaria zippei
Nodosaria sp.A
Frondicularia sp.A
Frondicularia sp.C
Frondicularia angulosa
Frondicularia inversa
Saracenaria triangularis
Marginulina cf. compressa
Marginulina bullata
Dentalina catenula
Dentalina pseudofiliformis
Planularia liebusi
Guttulina trigonula
Globulina prisca
Nodosaria naumanni
Frondicularia striatula
Dentalina megalopolitana
Lagena isabella
Nodosaria sp.C
Nodosaria aspera
Lenticulina sp.A
Marginulina sp.B
Neoflabellina baudouiniana
Lagena ellipsoidalis
Frondicularia archiaciana
Dentalina nana
Marginulina sp.A
Vaginulinopsis scalariformis
Citharinella sp.A
Pseudonodosaria obesa
LITUOLACEA
Arenobulimina obliqua s.l.
Arenobulimina courta
Marssonella oxycona
Eggerellina gibbosa var. globulosa
Eggerellina gibbosa var. conica
Verneuilina münsteri
Verneuilina sp.A
Ataxophragmium variabile
Gaudryina frankei
Gaudryina jonesiana
Dorothia pupa
Arenobulimina cf. polonica
Tritaxia tricarinata
Bigenerina sp.A
Reophax sp.A
Selected species < 250 µ size
Hedbergella cf. planispira
Heterohelix globulosa
Loxostomum eleyi
Cibicides sp.A
Praebulimina obtusa
Eouvigerina sp.C
Eouvigerina aculeata
Reussella cf. cushmani
Globigerinelloides ehrenbergi
7(b): NEWTON-BY-CASTLEACRE, NORFOLK.
STAGE
CONIACIAN
MACROFOSSIL ZONE
Micraster coranguinum
% PLANKTONIC FORAMINIFERA
SPECIES
250-500 µ
GLOBIGERINACEA
Whiteinella baltica
Globotruncana marginata
Globotruncana pseudolinneiana
Globotruncana canaliculata
Globotruncana bulloides
Archaeoglobigerina bosquensis
CASSIDULINACEA
Gavelinella ammonoides
Gavelinella pertusa
Gyroidinoides nitidus
Globorotalites cushmani
Quadrimorphina allomorphinoides
Lingulogavelinella sp.A
Stensioina granulata
Osangularia whitei var. whitei
Gavelinella thalmanni
Stensioina exsculpta exsculpta
Stensioina granulata var.A
Pleurostomella subnodosus
Gavelinella tumida
Osangularia whitei var. praeceps
DISCORBACEA
Valvulineria lenticula
ORB.
Eponides cf. concinna
BULIMINACEA
Praebulimina reussi
Reussella kelleri
NODOSARIACEA
Lenticulina rotulata s.l.
Lenticulina ovalis
Ramulina aculeata
Nodosaria sp.(indet.)
Dentalina megalopolitana
Frondicularia sp.A
Frondicularia angulosa
Frondicularia goldfussi
Saracenaria triangularis
Marginulina cf. compressa
Marginulina sp.A
Guttulina trigonula
Lenticulina sp.A
Nodosaria naumanni
Planularia liebusi
Dentalina catenula
Neoflabellina baudouiniana
Neoflabellina deltoidea
LITUOLACEA
Arenobulimina obliqua s.l.
Marssonella oxycona
Eggerellina gibbosa var. globulosa
Verneuilina münsteri
Gaudryina frankei
Dorothia pupa
Tritaxia tricarinata
Ammodiscus cretaceus
Arenobulimina courta
Eggerellina gibbosa var. conica
Gaudryina jonesiana
Reophax sp.A
Arenobulimina cf. polonica
Ataxophragmium variabile
Arenobulimina sp.A
Spiroplectammina anceps
Verneuilina sp.A
Bigenerina sp.A
Selected species < 250 µ
Eouvigerina aculeata
Globigerinelloides rowei
Heterohelix globulosa
Praebulimina obtusa
Nodosaria aspera
Ellipsoidella pleurostomelloides
Lagena hispida
Cibicides sp.A
Heterohelix reussi
Eouvigerina sp.C
C
ASSEMBLAGE ZONE
7(c): HELHOUGHTON, NORFOLK.
BURNHAM OVERY, NORFOLK (Single sample)
STAGE
SANTONIAN
MACROFOSSIL ZONE
M.coranguinum
% PLANKTONIC FORAMINIFERA
SPECIES
250-500 µ
GLOBIGERINACEA
Hedbergella brittonensis
Whiteinella baltica
Globotruncana marginata
Globotruncana pseudolinneiana
Globotruncana canaliculata
Globotruncana bulloides
Globotruncana linneiana
Archaeoglobigerina bosquensis
CASSIDULINACEA
Gavelinella ammonoides
Gavelinella pertusa
Gyroidinoides nitidus
Globorotalites cushmani
Lingulogavelinella sp.A
Stensioina granulata
Stensioina exsculpta exsculpta
Osangularia whitei var. whitei
Gavelinella thalmanni
Osangularia whitei var. praeceps
Quadrimorphina allomorphinoides
Stensioina granulata var.A
DISCORBACEA
Valvulineria lenticula
ORBIT.
Cibicides beaumontianus
Eponides cf. concinna
BULIMINACEA
Reussella kelleri
Praebulimina obtusa
Praebulimina reussi
NODOSARIACEA
Lenticulina rotulata s.l.
Lenticulina ovalis
Ramulina aculeata
Saracenaria triangularis
Dentalina nana
Marginulina bullata
Neoflabellina baudouiniana
Neoflabellina deltoidea
Neoflabellina praerugosa
Frondicularia sp.(indet.)
Planularia liebusi
Frondicularia angulosa
Nodosaria zippei
Lagena hispida
Lenticulina sp.A
Marginulina sp.A
Frondicularia goldfussi
Vaginulinopsis scalariformis
Nodosaria sp.(indet.)
Marginulina cf. compressa
LITUOLACEA
Arenobulimina obliqua s.l.
Ammodiscus cretaceus
Bigenerina sp.A
Dorothia pupa
Eggerellina gibbosa var. globulosa
Gaudryina frankei
Marssonella oxycona
Tritaxia tricarinata
Verneuilina sp.A
Verneuilina münsteri
Arenobulimina cf. polonica
Arenobulimina courta
Ataxophragmium variabile
Gaudryina jonesiana
Spiroplectammina anceps
Selected species < 250 µ
Loxostomum eleyi
Nodosaria naumanni
Heterohelix globulosa
Dentalina pseudofiliformis
Eouvigerina aculeata
Globigerinelloides ehrenbergi
Praebulimina obtusa
Reophax sp.A
Eouvigerina sp.C
Cibicides sp.A
Pleurostomella subnodosus
D C D
ASSEMBLAGE ZONES
7(d): THAMES BARRIER SITE INVESTIGATION, B.H. No.52.
STAGE
CONIACIAN
MACROFOSSIL ZONE
Micraster cortestudinarium
% PLANKTONIC FORAMINIFERA
SPECIES
250-500 µ
GLOBIGERINACEA
Hedbergella brittonensis
Globotruncana marginata
Globotruncana pseudolinneiana
Globotruncana bulloides
Globotruncana angusticarinata
Globotruncana renzi
Whiteinella baltica
CASSIDULINACEA
Gavelinella ammonoides
Globorotalites cushmani
Gyroidinoides nitidus
Lingulogavelinella sp.A
Gavelinella pertusa
Quadrimorphina allomorphinoides
Stensioina granulata
Osangularia whitei var. whitei
Gavelinella thalmanni
Stensioina exsculpta exsculpta
Pleurostomella subnodosus
DISCORBACEA
Valvulineria lenticula
ORB.
Cibicides sp.A
BULIMINACEA
Reussella kelleri
Praebulimina obtusa
NODOSARIACEA
Lenticulina rotulata s.l.
Frondicularia sp.C
Saracenaria triangularis
Marginulina sp.A
Nodosaria sp.(indet.)
Frondicularia sp.A
Neoflabellina praerugosa
Lenticulina ovalis
Nodosaria sp.A
Frondicularia angulosa
Nodosaria zippei
Ramulina aculeata
Marginulina sp.B
Neoflabellina baudouiniana
Frondicularia striatula
Planularia liebusi
Guttulina trigonula
Marginulina cf. compressa
Nodosaria naumanni
Vaginulinopsis scalariformis
Frondicularia archiaciana
LITUOLACEA
Ataxophragmium variabile
Marssonella oxycona
Arenobulimina obliqua s.l.
Arenobulimina courta
Spiroplectammina anceps
Verneuilina sp.A
Verneuilina münsteri
Eggerellina gibbosa var. globulosa
Tritaxia tricarinata
Gaudryina frankei
Arenobulimina sp.(indet.)
Arenobulimina sp.A
Eggerellina gibbosa var. conica
Reophax sp.A
Gaudryina jonesiana
Dorothia pupa
Bigenerina sp.A
Selected species < 250 µ
Heterohelix globulosa
Praebulimina obtusa
Cibicides sp.A
Eouvigerina stormi
Reophax sp.A
Pleurostomella subnodosus
Eouvigerina aculeata
Loxostomum eleyi
A B C
ASSEMBLAGE ZONES
7(e): I.G.S. BOREHOLES, ESSEX.
WITHAM
SANTON.
M.corang.
KELVEDON
SANTONIAN
M.corang.
STAGE
MACROFOSSIL ZONE
% PLANKTONIC FORAMINIFERA
SPECIES
250-500 µ
GLOBIGERINACEA
Globotruncana bulloides
Globotruncana canaliculata
Globotruncana linneiana
Globotruncana concavata
Archaeoglobigerina bosquensis
CASSIDULINACEA
Gavelinella ammonoides
Gavelinella sp.A
Gavelinella pertusa
Globorotalites cushmani
Gyroidinoides nitidus
Osangularia whitei var. whitei
Stensioina exsculpta exsculpta
Stensioina exsculpta gracilis
Stensioina granulata var.A
Gavelinella cf. clementiana
Gavelinella thalmanni
DISCORBACEA
Valvulineria lenticula
ORBITOIDACEA
Cibicides beaumontianus
Eponides cf. concinna
Cibicides beaumontianus var.A
Cibicides ribbingi
BULIMINACEA
Praebulimina reussi
Reussella szajnochae praecursor
NODOSARIACEA
Lenticulina rotulata
Lenticulina ovalis
Lenticulina sp.A
Frondicularia sp.A
Guttulina trigonula
Neoflabellina praerugosa
Ramulina aculeata
Dentalina pseudofiliformis
Frondicularia angulosa
Neoflabellina baudouiniana
Neoflabellina deltoidea
Dentalina catenula
Dentalina megalopolitana
Nodosaria zippei
LITUOLACEA
Arenobulimina obliqua s.l.
Arenobulimina cf. polonica
Ataxophragmium variabile
Dorothia pupa
Eggerellina gibbosa var. globulosa
Gaudryina frankei
Gaudryina jonesiana
Marssonella oxycona
Spiroplectammina anceps
Verneuilina münsteri
Arenobulimina courta
Verneuilina sp.A
Tritaxia tricarinata
Selected species < 250 µ size fraction
Cibicides sp.A
Eouvigerina aculeata
Eouvigerina sp.C
Globigerinelloides asperus
Heterohelix globulosa
Lagena isabella
Loxostomum eleyi
Citharina cf. strigillata
Globigerinelloides ehrenbergi
Pleurostomella subnodosus
Praebulimina obtusa
Pyramidina cf. buliminoides
Quadrimorphina trochoides
F F
ASSEMBLAGE ZONES


Ramulina aculeata
Dentalina pseudofiliformis
Frondicularia angulosa
Neoflabellina baudouiniana
Neoflabellina deltoidea
Dentalina catenula
Dentalina megalopolitana
Nodosaria zippei
DOSARIACEA
Arenobulimina obliqua s.l.
Arenobulimina cf. polonica
Ataxophragmium variabile
Dorothia pupa
Eggerellina gibbosa var. globulosa
Gaudryina frankei
Gaudryina jonesiana
Marssonella oxycona
Spiroplectammina anceps
Verneuilina münsteri
Arenobulimina courta
Verneuilina sp.A
Tritaxia tricarinata
LITUOLACEA
Cibicides sp.A
Eouvigerina aculeata
Eouvigerina sp.C
Globigerinelloides asperus
Heterohelix globulosa
Lagena isabella
Loxostomum eleyi
Citharina cf. strigillata
Globigerinelloides ehrenbergi
Pleurostomella subnodosus
Praebulimina obtusa
Pyramidina cf. buliminoides
Quadrimorphina trochoides
Selected species < 250µ size fraction
F
F
ASSEMBLAGE ZONES


Neoflabellina praerugosa
Lenticulina ovalis
Nodosaria sp.A
Frondicularia angulosa
Nodosaria zippei
Ramulina aculeata
Marginulina sp.B
Neoflabellina baudouiniana
Frondicularia striatula
Planularia liebusi
Guttulina trigonula
Marginulina cf. compressa
Nodosaria naumanni
Vaginulinopsis scalariformis
Frondicularia archiaciana
NODOSARIACEA
Ataxophragmium variabile
Marssonella oxycona
Arenobulimina obliqua s.l.
Arenobulimina courta
Spiroplectammina anceps
Verneuilina sp.A
Verneuilina münsteri
Eggerellina gibbosa var. globulosa
Tritaxia tricarinata
Gaudryina frankei
Arenobulimina sp. (indet.)
Arenobulimina sp.A
Eggerellina gibbosa var. conica
Reophax sp.A
Gaudryina jonesiana
Dorothia pupa
Bigenerina sp.A
LITUOLACEA
Heterohelix globulosa
Praebulimina obtusa
Cibicides sp.A
Eouvigerina stormi
Reophax sp.A
Pleurostomella subnodosus
Eouvigerina aculeata
Loxostomum eleyi
Selected species < 250µ
A
B
C
ASSEMBLAGE ZONES


Ramulina aculeata
Saracenaria triangularis
Dentalina nana
Marginulina bullata
Neoflabellina baudouiniana
Neoflabellina deltoidea
Neoflabellina praerugosa
Frondicularia sp. (indet.)
Planularia liebusi
Frondicularia angulosa
Nodosaria zippei
Lagena hispida
Lenticulina sp.A
Marginulina sp.A
Frondicularia goldfussi
Vaginulinopsis scalariformis
Nodosaria sp. (indet.)
Marginulina cf. compressa
NODOSARIACEA
Arenobulimina obliqua s.l.
Ammodiscus cretaceus
Bigenerina sp.A
Dorothia pupa
Eggerellina gibbosa var. globulosa
Gaudryina frankei
Marssonella oxycona
Tritaxia tricarinata
Verneuilina sp.A
Verneuilina münsteri
Arenobulimina cf. polonica
Arenobulimina courta
Ataxophragmium variabile
Gaudryina jonesiana
Spiroplectammina anceps
LITUOLACEA
Loxostomum eleyi
Nodosaria naumanni
Heterohelix globulosa
Dentalina pseudofiliformis
Eouvigerina aculeata
Globigerinelloides ehrenbergi
Praebulimina obtusa
Reophax sp.A
Eouvigerina sp.C
Cibicides sp.A
Pleurostomella subnodosus
Selected species < 250µ
D
C
D
ASSEMBLAGE ZONES


Frondicularia angulosa
Frondicularia goldfussi
Saracenaria triangularis
Marginulina cf. compressa
Marginulina sp.A
Guttulina trigonula
Lenticulina sp.A
Nodosaria naumanni
Planularia liebusi
Dentalina catenula
Neoflabellina baudouiniana
Neoflabellina deltoidea
NODOSARIACEA
Arenobulimina obliqua s.l.
Marssonella oxycona
Eggerellina gibbosa var. globulosa
Verneuilina münsteri
Gaudryina frankei
Dorothia pupa
Tritaxia tricarinata
Ammodiscus cretaceus
Arenobulimina courta
Eggerellina gibbosa var. conica
Gaudryina jonesiana
Reophax sp.A
Arenobulimina cf. polonica
Ataxophragmium variabile
Arenobulimina sp.A
Spiroplectammina anceps
Verneuilina sp.A
Bigenerina sp.A
LITUOLACEA
Eouvigerina aculeata
Globigerinelloides rowei
Heterohelix globulosa
Praebulimina obtusa
Nodosaria aspera
Ellipsoidella pleurostomelloides
Lagena hispida
Cibicides sp.A
Heterohelix reussi
Eouvigerina sp.C
Selected species < 250µ
C
ASSEMBLAGE ZONE


Lenticulina rotulata s.l.
Lenticulina ovalis
Ramulina aculeata
Neoflabellina praerugosa
Neoflabellina deltoidea
Nodosaria zippei
Nodosaria sp.A.
Frondicularia sp.A
Frondicularia sp.C
Frondicularia angulosa
Frondicularia inversa
Saracenaria triangularis
Marginulina cf. compressa
Marginulina bullata
Dentalina catenula
Dentalina pseudofiliformis
Planularia liebusi
Guttulina trigonula
Globulina prisca
Nodosaria naumanni
Frondicularia striatula
Dentalina megalopolitana
Lagena isabella
Nodosaria sp.C
Nodosaria aspera
Lenticulina sp.A
Marginulina sp.B
Neoflabellina baudouiniana
Lagena ellipsoidalis
Frondicularia archiaciana
Dentalina nana
Marginulina sp.A
Vaginulinopsis scalariformis
Citharinella sp.A
Pseudonodosaria obesa
NODOSARIACEA
Arenobulimina obliqua s.l.
Arenobulimina courta
Marssonella oxycona
Eggerellina gibbosa var. globulosa
Eggerellina gibbosa var. conica
Verneuilina münsteri
Verneuilina sp.A
Ataxophragmium variabile
Gaudryina frankei
Gaudryina jonesiana
Dorothia pupa
Arenobulimina cf. polonica
Tritaxia tricarinata
Bigenerina sp.A
Reophax sp.A
LITUOLACEA
Hedbergella cf. planispira
Heterohelix globulosa
Loxostomum eleyi
Cibicides sp.A
Praebulimina obtusa
Eouvigerina sp.C
Eouvigerina aculeata
Reussella cf. cushmani
Globigerinelloides ehrenbergi
Reophax sp.A
Spiroplectammina anceps
Globigerinelloides rowei
Praebulimina parva
Pyramidina cf. buliminoides
Cibicides beaumontianus var. A
Selected species < 250µ size fraction
D
E
ASSEMBLAGE ZONES

ENCLOSURE 5: THAMES BARRIER SITE INVESTIGATION.

EXTRACT

PROCEEDINGS

OF THE

USSHER SOCIETY

VOLUME THREE

PART TWO

1975

A PRELIMINARY MICROFAUNAL INVESTIGATION OF THE LOWER SENONIAN AT BEER, SOUTH-EAST DEVON

by H. W. Bailey

Abstract. The position of the Turonian — Senonian stage boundary at Beer is discussed in the light of recent work carried out on the microfaunal assemblage and its correlation with the macrofauna. Changes in the Globigerinacea are used as indicators in the recognition of this boundary.

1. Introduction

Previous workers on the microfauna of the Upper Cretaceous succession at Beer have examined almost all the exposed chalk strata. The Albian and Cenomanian stages have been studied by Hart (1970, 1971, 1973) and the Turonian stage by Owen (1970).

Owen, however, did not examine the junction between the Turonian stage and the Coniacian sub-stage which, if Rowes' (1903) macrofossil zones are used, corresponds to the *Holaster planus* — *Micraster cortestudinarium* zonal boundary. Rowe used a lithological correlation from the Pinhay Bay section to establish the macrofaunal boundary in the cliff exposure at Beer, known locally as Annis' Knob (SY 232892). Jukes-Browne and Hill (1904), in some disagreement with Rowe, placed the top of the *Holaster planus* Zone approximately 4 metres lower at the base of a prominent, black, tabular flint, 0.13 metres thick. This flint is found approximately 5 metres above the base of the section.

The usefulness of this lithological boundary in the field has been proven by a preliminary investigation of the macrofauna. The brachiopod *Orbirhynchia cuvieri* (d'Orbigny) is found in some abundance at a level 1.4 metres below the tabular flint, which suggests a Turonian age for this horizon. A Coniacian age has been attributed to the beds above the flint because of the abundance of *Micraster cortestudinarium* (Goldfuss) two to three metres above the boundary. An examination of the microfauna from this section has been made to see if there is any correlation with the macrofaunal succession.

Samples were taken initially at one metre intervals; later it was found that a more detailed examination of the chalk immediately above the flint was required. The sampling interval was therefore reduced to 0.25 metres over this part of the section. The study is based on total counts of the foraminiferal assemblage found in the 30-60 (0.50-0.25mm) grain size fraction, as it is within this size range that the majority of the mature, adult individuals are contained. Other size fractions have been studied but not counted.

2. Lithological succession

The Annis' Knob section is approximately 11 metres thick, although a further 6 metres can be added by a second cliff section, separated from the first by a belt of brecciated chalk which probably represents a minor fault. The displacement along this fault is difficult to determine, but it probably throws down a few metres towards the east. It is hoped that the microfauna taken from the second section will give some indication of its stratigraphical position.

The whole of the exposure has a rubbly, nodular appearance on the exposed, weathered cliff face, but minor variations allow a division into three distinct lithological units:

(i) Below the tabular flint the grey/white chalk shows a relatively high clay content in the form of abundant diagenetic solution seams. This reaches an extreme at the base of the section where clean surfaces have the appearance of white chalk nodules within a matrix of dark grey marl. Grains of phosphatic material, including microcoprolites, are common in this unit, as are discrete grains of glauconite which are occasionally in the form of indeterminate foraminiferal chamber infillings. Unfortunately it is not clear whether the glauconite grains were formed in situ or derived from a source (such as the Lower Chalk) in which glauconite is extremely abundant. Scattered flints occur throughout this unit, the base of which is marked by a nodular flint band.

(ii) Immediately above the 0.13 metre tabular flint there is a pale cream flintless horizon, rich in marl solution seams. This forms a distinctive base to the second unit which continues to the top of the cliff as a very nodular chalk characterized by the presence of hard, yellow/brown phosphatic horizons. These range in thickness from 0.10 to 0.40 metres and are extremely nodular. As the rock is too hard to crush, many of the samples taken from the upper part of the cliff were thin-sectioned. Assemblage counts cannot be made on material prepared in this way, so that these samples were used for identification purposes only. Numerous *M. cortestudinarium* occur within these phosphatic bands. Scattered flints and microcoprolites are again present but glauconite is absent from samples taken over 1.4 metres above the tabular flint.

(iii) The section to the east of the fault provides the third lithological unit. The base is marked by a phosphatic horizon, but between this and the top of the section, which shows a pale yellow colouration (possibly due to phosphate content), the chalk has a smooth texture and lacks the nodular character of the cliff. Large, scattered nodular flints are present throughout the unit, but banding becomes apparent towards the top.

3. Microfaunal succession

The benthonic foraminifera of the superfamilies Lituolacea, Nodosariacea and Cassidulacea are by far the most dominant part of the microfauna, often totalling over 95% of the assemblage. Whilst these groups show minor variations which could be interpreted as being of stratigraphic significance locally, it is the planktonic foraminifera which provide the major changes that may be used for wider correlation.

The planktonic population (Fig. 1) has been divided into four types. Those with simple round inflated chambers and an umbilical aperture have been identified as *Whiteinella* sp. The others are referred to *Globotruncana bulloides* Vogler, *Globotruncana pseudolinneiana* (Pessagno) and *Globotruncana* sp., which appears to be an intermediate morphological form between the other two species.

Owen (1970) uses *G. pseudolinneiana* as the index species of the highest planktonic foraminiferal subzone of the Turonian. The results shown on the graph (Fig. 1) appear to confirm this (as in the lowest lithological unit, *G. pseudolinneiana* is the most abundant representative of the genus). The most important feature is the

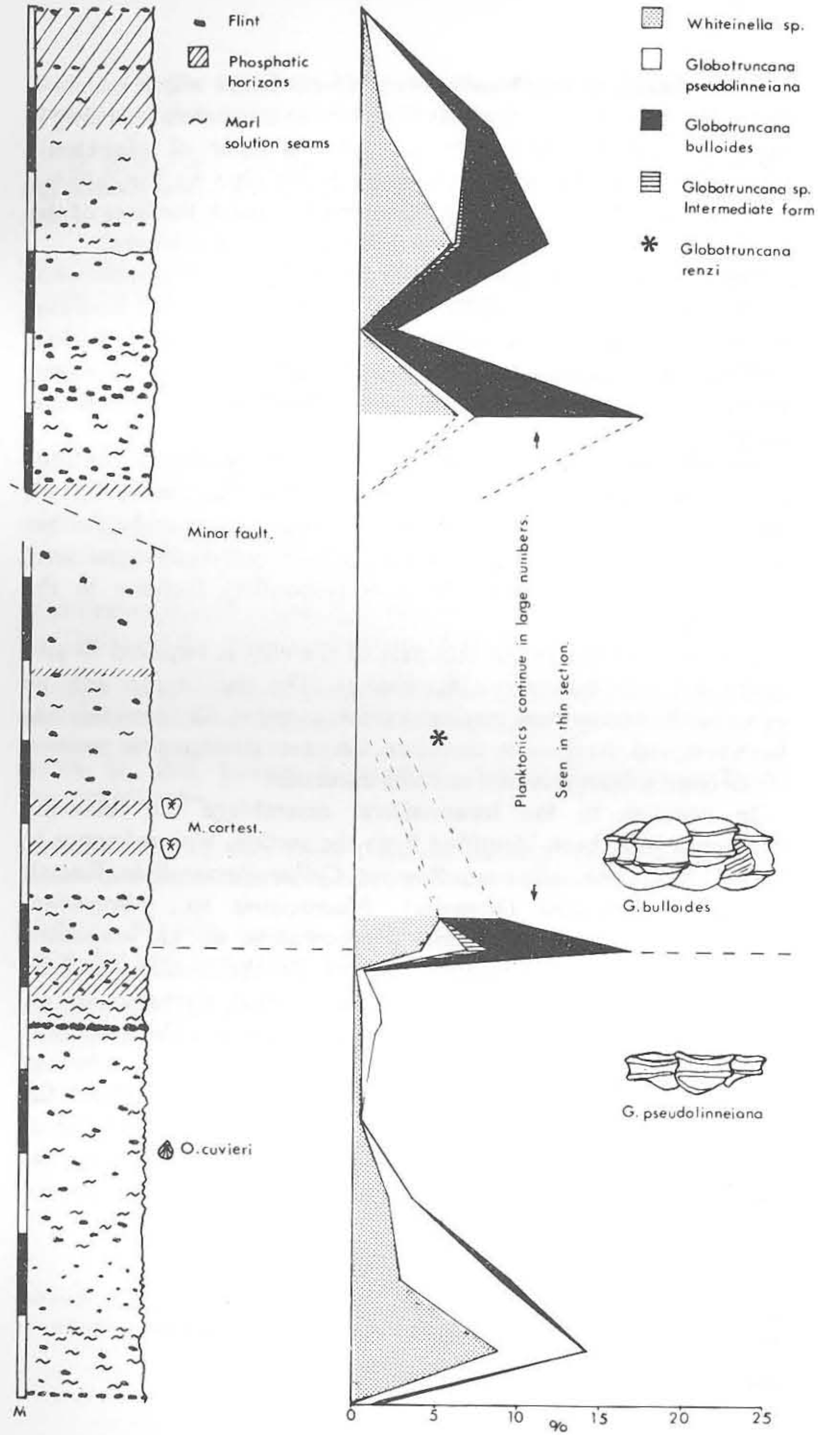


FIGURE 1. Lithological section of Annis' Knob, Beer, and graph to show planktonic foraminiferal count expressed as a percentage of the total foraminiferal assemblage. *(M. cortest. — Micraster cortestudinarium, O. cuvieri — Orbirhynchia cuvieri.)*

distinct change in planktonic foraminiferal fauna which occurs 1 metre above the tabular flint. At this point in the section, not only is there a marked increase in the total number of planktonic foraminifera, but *G. pseudolinneiana* is replaced by the inflated form *G. bulloides*. This change is believed to mark the base of the Coniacian sub-stage, and thus the Senonian stage in this area.

The Coniacian age is confirmed 3 metres higher by the presence of *Globotruncana renzi* Gandolfi, which is used as the zonal indicator for the sub-stage in more southerly regions such as Trinidad (Bolli 1957) and the Western Gulf Coastal Plain of the U.S.A. (Pessagno 1967), and which is considered to be a Tethyan form (Douglas and Rankin 1969).

The planktonic forms *G. bulloides* and *Whiteinella* sp. continue in large numbers in those samples which have been thin-sectioned, and it is only at the top of the third lithological unit that a further faunal change is apparent. This is recorded as a total disappearance of the planktonic fauna with a corresponding increase in the Cassidulacea.

Further examination of this part of the cliff is required to give additional information on this change. The section can only be extended by two to three metres at most, as the chalk above this has been removed. At present, therefore, the exact stratigraphic position of the third lithological unit remains uncertain.

In addition to the foraminiferal assemblage the following Ostracoda have been identified from the section, with reference to Kaye (1964): *Cytherella ovata* Roemer, *Cytherella parallela* (Reuss), *Bairdia subdeltoidea* (Munster), *Macrocypris* sp., *Neocythere (Physocythere) virginea* (Jones), *Monoceratina* sp. cf. *umbonata* (Williamson), *Veenia harrisiana* (Jones), *Trachylebridea acutiloba* (Marsson), *Cythereis* sp. cf. *lurmannae* Triebel, *Cythereis* sp. cf. *ornatissima* (Reuss), *Cytherelloidea hindei* Kaye and *Cytherelloidea oblinquirugata* (Jones and Hinde).

C. ovata and *C. parallela* have a distribution throughout the whole section. The others, apart from *Macrocypris* sp., appear as scattered individual specimens at various levels. *Macrocypris* sp. has been separated off as it appears to be common only in the second cliff section.

ACKNOWLEDGEMENTS. I would like to express my thanks to Dr. M. B. Hart for his assistance throughout this project and to Mr. P. Weaver for his comments on the Ostracoda. The data on which this work is based form part of a Ph.D. project financed as a L.E.A. Research Assistantship.

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